Mechanick Powers:

OR, THE

MISTERY OF NATURE and ART UNVAIL'D.

Shewing what *Great Things* may be perform'd by Mechanick Engines, in removing and raising Bodies of vast Weights with little Strength, or Force; and also the making of Machines, or Engines, for raising of Water, draining of Grounds, and several other Uses.

TOGETHER

With a Treatise of *Circular Motion* artificially fitted to Mechanick use, and the making of Clock-work, and other Engines.

A Work pleasant and profitable for all sorts of Men, from the highest to the lowest Degree: And never treated of in *English* but once before, and that but briefly.

The whole comprized in Ten Books, *and Illustrated with Copper Cuts.*

the Second Edition.

By *Ven. Mandey* and *J. Moxon*, Philomat.

LONDON,
Printed and Sold by *Ven. Mandey*, next door to the *Saloon* in *Bloomsbury Market*, and *James Moxon*, at the *Atlas* in *Warwick-Lane*, and at the Corner of *Ave-Mary-Lane*, in *Ludgate Street*. 1699.

To His GRACE,

WILLIAM,

Duke *of* BEDFORD,

Marquiſs of *TAVISTOCK*, Lord *RUSSEL*, Baron *Ruſſel* of *Thornhaugh*, and Baron *Howland* of *Streatham*, Knight of the Moſt Noble Order of the *GARTER*, Lord Lieutenant of the Counties of *Middleſex*, *Cambridge* and *Bedford*, and One of his Majeſty's Moſt Honourable *PRIVY COUNCIL*,

VENTERUS MANDEY

and

JAMES MOXON,

In teſtimony of the Honour and reſpective Obſervance they bear to that Noble Duke, humbly Publiſh and Dedicate this their enſuing TREATISE.

To the READER.

AMong the chiefest and most useful ARTS, *which God, the most wise Artificer, hath granted to Mankind, this Noble* Mechanick Art *is not the meanest, and yet nevertheless, for the most part, the least regarded, which I much admire; it being of such general Use for all sorts of Men, in making of Mills of various kinds, for Grindeing, Sawing, Pounding,* &c. *and Engines for making Mines, and Coal-Pits, Raising of Water, and other heavy Bodies, likewise in making Clocks and Watches,* &c. *and also for several other Uses, too long to insert here. This Work hath been largely Treated of by several ingenious Men; in* Italian, French, High-Dutch *and* Latin, *viz.* Archimedes, Aristotle, Schottus, Stevinus, Guido Ubal-dus, Meresnnus, Dechales *and* Cassatus, *but most largly and learnedly by our Reverend Country-man Dr.* Wallis *in his* Mechanica, *and by several others, which I omit naming; no one having writ of it in our Native Language that I have seen or heard of, but the Reverend Bishop* Wilkins, *and he but briefly, and rather Historically than fundamentally. In the following Treatise we have Collected those things which are most pertinent to the Work, and divided the whole Treatise into* 10 *Books, an account whereof you have in the following Pages; which being as kindly received, as they are freely offered, will obliege those who are friends to all, but especially to them that are Mathematically inclined.*

V. M. *and* J. M.

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Of

Mechanick

Mechanick-Powers:

OR, THE

Myſtery of *Nature* and *Art* unvail'd.

BOOK I.

THE *Mechanick Art* is a Science which contemplates about the quantities of moving Forces, and of the times in which the Motion is made.

The Centre of Gravity of any Body is a certain point within it, having the parts about it every where conſiſting of equal moments according to which it is born downward, and from whence if a body be conceived to be hung by a Line it reſteth while it bears downward, keeping the Poſition which it had in the beginning, and that Line is always perpendicular to the Horizon.

PROPOS. I.

VArious are theEngins,to which if force be uſed,their ſtrengths are augmented in a wonderful manner, ſo that, that which is fit to overcome the reſiſtance of 100 pound weight, may be made ſufficient to overcome 1000 pound, yea, 2000 pound weight, and more: I will expound this Propoſition, which cannot be done better than by ſimply expoſing to view the Engines, whoſe forces are increaſed by the ſtrength of their movers, and we will ſhew what Experience approves in common Engins; and becauſe almoſt all Authors recal the other Powers to the Ballance, we will begin with it.

Of the Ballance.

BY the *Ballance* we underſtand an iron Rod, hanging freely in the middle point which is called the *Beam*, or *Centre*; and the effect which daily experience teaches us is this.

Fig. 1. If two equal Weights ſuppoſe of 4 pound each be hung in the points A and B, ſo that the lines A C, C B are equal, they will poiſe each other, or be in *Equilibrio*. But if the weight F be never ſo little removed from the *Beam* or *Cock* C, ſo that the line B C be longer than the line A C, the weight F overcomes and raiſes the weight E; if you ask why thoſe forces are increaſed by their greater diſtance from the *Beam*, or *Centre*, ſo that the diſtance augmented is equivalent to the weight; that is, ſuppoſe two unequal weights E and G, and let the proportion of the weight E to the weight G, be the ſame as the diſtance C H to the diſtance A C; and that the weight at H compenſates or makes amens in the diſtance for that which it wants in the Gravity or weight, ſo that they ſtill remain in *equilibrio*, (or equally poiſed) therefore it is queſtioned, wherefore the diſtance from the beam adminiſters ſufficient ſtrength to it to reſiſt double its weight; which is ſo far forth a truth, that if the line or rod C H being produced farther in certain diviſions, the ſame weight, ſuppoſe one pound, will according to the ſeveral diſtances equiponderate to any weight, or number of pounds hung in the point A, and this kind of *Ballance* is in uſe every where, for Butchers weigh their meat by it, and Farmers their Hay, *&c.* Only Note this one thing, which in all Engines ought to be noted, to wit, as often as the force of the power is increaſed by the Engin, ſo often alſo is its motion increaſed with reſpect to the motion of the weight; as in the former example, while the weight G is at the diſtance C H, being double the diſtance of A C, all things being ſo diſpoſed, if you remove the weight E one foot, the weight G muſt be removed 2 feet, ſince it deſcribes an Arch doubly greater, or as great again.

Of the Leaver.

THe ſecond Engin which is propoſed is the *Leaver*, which is a firm body extended in length, as a Bar of Iron or a wooden Bar of firm ſubſtance, in which three things are always

ways to be distinguished; to wit, the power of the Movent, the Weight to be moved, and the point that sustains the *Leaver*, which is called *Hypomoclion* or *Prop*, being nothing but a Roller or a piece of Timber or Stone laid under the *Leaver*, to support it, even as in the Ballance we distinguish three things, to wit, the two Weights and the Beam or Cock; whence it comes to pass that the *Leaver* is compared to the Ballance. And because the *Hypomoclion* may possess either the middle place between the power and the weight, or it may be in one of the extreams or ends, and that two fold, to wit, either so that the weight may possess the middle place, or else the power may be in the middle, therefore there are three kinds of *Leavers*.

Fig. 2. The first kind of *Leaver* hath the weight on one end A, the Power in the other end C, and the *Hypomoclion* in the middle, to wit, in the point B, and if the power happen to be equally distant from the *Hypomoclion*, with the weight, and so equally moved; In such disposition if the power can of it self and without an *Engin* move 100 pound, and the weight A be just 100 pound, it may move that and no more; but if the distance B C be greater than the distance A B, suppose double to it, and being so disposed, while the weight is moved one foot, the Power C performs 2 feet, then the same power being placed in C, will raise or overcome 200 pound in A.

The same proportion in a manner is said to be in the second kind of *Leaver*, for because the distance D F exceeds the distance D E, therefore the power placed in F, will be increased according proportion of the line D F to the line D E.

The third kind of *Leaver* increases not the force of the Power, but rather increases the force and resistance of the weight, and lessens the force of the power; beeause the distance of the power H from the *Hypomoclion* G, is less than the distance G I of the weight from the same *Hypomoclion*; and consequently in such disposition the power is less moved than the weight.

Of the Wheel, or Axis, in Peritrochio. Fig. 3.

THe *Wheel*, or *Axis*, in *Peritrochio* may be variously used, and this Figure expresses it sufficiently, The power will be in the point F, and the weight in the point D; it may easily be reduced to the *Leaver* of the first or second kind; For its *Axis* A B hath the force of the *Hypomoclion*, and because the weight is

in D, its distance will be C D and the distance of the power applied in F will be E F; Therefore the active force of the power will be increased according to the *Ratio* or proportion of the line E F to C D, that is, if E F be four times as much as C D, and the power without an *Engin* may take up 100 pound weight; it being added to such an *Engin* may take up or draw 400 pound weight; Here we shall offer no reason, but expose the precise effect and experience; Wherein we would note one thing, that the precise distance from the *Hypomoclion* doth not conferr this augmentation, but that distance from whence follows the greater motion in the power, will respect to the motion of the weight, that is, if the Power H should draw by the rope F H, the distance H E is not to be regarded, but only F E, because although the length of the rope increase and consequently the distance H E; notwithstanding from that distance it doth not follow, that while the weight is moved one foot, the power is moved more than four feet.

Of the Pulley or Windless. Fig. 4.

THE single *Pulley* increases not force, and is reduced to the *Leaver*; notwithstanding being so composed that the distance of the weight and of the Power are equal, and these distances are D B, B E from the immoveable point B; and since no *Pulley* hath motion, but about the Fixed point B, therefore the forces are not increased, if the principle we prosecute be constituted, because the power is as well moved as the weight. The only benefit that accrues from the *Pulley* in this disposition, is that the power may be more easily applied, and to shun the resistance which may happen by accident, because the rope being turn'd about an immoveable Cylinder is fretted and worn.

The Pulley *may be disposed after another manner.*

Fig. 5. It may be made so that the whole *Pulley* may move, supposing one end of the rope fastned in A, and the weight G, the Power F, and this is commonly reduced to the Second kind of *Leaver*, for the *Hypomoclion* is supposed in B, the weight G is in E, and the power F is in D, and therefore the distance

of

of the power is double from the *Hypomoclion*, and while the weight G aſcends to H, the Power F will be moved to a double diſtance : It is not needful here to ſhew all the Combinations of *Pulleys*, but only in this caſe to ſhew the double force of the power, and that force which before was equal to 100 pound weight, by this diſpoſition may be made equal to 200 pound weight.

Of the Wedge. Fig. 6.

THE *Wedge* is an Inſtrument made of ſollid matter, as *Iron* or *Wood* ending in a ſharp point or edge, As ABCDEF, ſome Authors ſtrive to reduce it to the *Leaver*, in which we are indifferent, and the *Wedge* ſeems to be a double *Leaver* of the ſecond kind, in which the *Hypomoclion* is in the line G H, the weight in R and K, the Power in L and M, but how ill they have reſented or reduced it, we will ſhew hereafter; However it be, it is certain the force of the Power is increaſed by the ſharpneſs of the *Wedge*, and the accuteneſs of the Angle, becauſe while the bodies which have the force of the weight, go back from one another by the line R K, the *Wedge* is moved according to the line I O: Add alſo, that the power which is ſtruck with a blow on the head of the *Wedge*, makes a greater motion, than the Power which is made by weight lying on the head of the *Wedge*.

Of the Screw. Fig. 7.

THe *Screw* is a moſt powerful Machine, or Engin, and is a Cylinder cut with a wreathed circle about it, which may be variouſly conſtituted and made: We ſhall not attempt to reduce it to the *Leaver*, but 'tis certain, that one man who can alone by his own ſtrength raiſe 100 pound, may by this Engin ſometimes raiſe 10000 pound. For let the weight be be D E, the Power C, in the mean while that the weight is moved according to the diſtance which is between two wreaths, or ſpires of the *Screw*, it is neceſſary that the power placed in the point C abſolves or finiſhes a whole Circle; therefore let the diſtance between the two wreaths be equal to the line N O, then ſeek how many times the line N O is con-

contained in the circumference of the circle C K L, if it be contained 100 times, the motion of the Power will be a hundred fold greater than the motion of the weight, as is proved by daily experience.

PROPOS. II.

Aristotle's *Reason, why the forces of Powers are encreased by the force of Engines, is Examined.*

ARistotle is the first that we know of that attempted this; we have often read his whole Treatise which he wrote of *Engines*, and confess we could never sufficiently find out the universal principle of Machines or Engines: For he attempts only to give the reason of the *Ballance*, and reduces the *Leaver* to the *Ballance*, and the other Machines or Engines he explicates by the *Leaver:* We shall do two things, First, we shall examine the Reason which he offers, as the only true and most likely for the *Ballance* in the middle. Secondly, we shall try whether those things which are said concerning the *Ballance*, may be said of the *Leaver*, and whether those things that belong to the *Leaver*, may be easily applied to the other Machines, or Engines: For he proposes some wonderful things from the Circle, and adds, that those things which are done about the *Ballance* are to be referred to the Circle, and those concerning the Leaver to the Ballance, and all other Motions concerning Engins he referrs to the *Leaver*.

Aristotle reasons thus, Every Power moving to the centre of the World is born down by a right line, and the weight thrusts forward, or the weight according to its quantity contributes to such motion; but when weight is moved in a Ballance then it is supposed to deviate from such rectitude, and by deviation it breaks off and retards the motion pressing forward from such power, and by how much more the motion produced by such power is retarded, by so much more decreases the force of that power in order to such motion; but because that which is nearest the Beam or Cock, is also nearest the

the retaining principal, and deviates more from right motion; therefore the moving power being applied in a point near the Cock, loses more of its force; and that which is more distant from the centre or cock, partakes less of motion; besides the nature of that motion comes nearer to right motion, and therefore its force is less hindred to exercise its power, wherefore that weight which is farthest distant from the Centre is easily moved, and although it be equal to the other weight weighing against it, and lest distant from the centre, it will be moved more easier, which to make more plain he institutes a geometrical Demonstration in this manner:

Fig. 8. Let the *Iron* rod A B be the Ballance, the *Beam* or Cock A, about which, as about a Centre, the whole rod A B is moved; and let the weight be B which descendeth by force of its own weight, and describes the arch B H; also let there be another weight C, which while it descends by its own gravity is consider'd according to the disposition of the Ballance, to describe the arch C D Y, less than the arch B E H: Suppose the weight C to descend to the point D, and draw the line D E, which let be parallel to the line A B, Suppose the weight B to descend to the point E, since the natural motion of heavy things is perpendicular, the lines F E, G D measure the natural motion of the bodies or weights, or the motion which is according to their Nature; But the lines C G, F B measure the preternatural motion, to wit, by whose force they are retracted from their lines of Direction, or perpendicular lines; but F B is less than C G; for if equal right lines fall perpendicularly on the Seme-diameter of unequal Circles, that which is in the greater circle cuts of the lesser part because the greatest circle is less crooked: Therefore while those two weights have an equal natural motion, that which is farthest distant from the Centre hath least of the preternatural motion, therefore the easier moved, and therefore hath greater force to move the other, and consequently comes to E in a shorter time, than the weight C comes to D.

Moreover he adds, because the motion of weight is equal in each, the motion which is according to nature is in it self the same to preternatural motion, but it only then happens when in the same time that C comes to D, in the same time also B comes to L; for then drawing the line I L perpendicular, it will be as I L to I B, so D G to G C; in the Triangles A G D, A L I (by *Prop.* 4. *El.*6.) so is I L to A I, as G D to A C; and as

A

A D or A C to A G or A K, ſo is A B to A I, therefore by diviſion, it will be as I L to I B, ſo G D to G C: When therefore it happens only in the point L, that the proportion aforeſaid is kept while the point C comes to D, the point B will come to L, therefore B is moved more ſwiftly. Theſe are *Ariſtotle's* words, *Quam igitur ob cauſam ab eâdem potentia celeriùs fertur, id quod plus a centro diſtat, ex iis quæ dicta ſunt eſt manifeſtum.* And Queſtion 3d. he ſays, *Quoniam autem ab æquali pondere celeriùs movetur eorum, quæ a centro ſunt; duo verò pondera quod movet, & quod movetur; quod igitur motum pondus, ad movens longitudo patitur ad longitudinem, ſemper autem quanto ab Hypomoclio diſtabit magis tanto facilius movebit.*

Many things are wanting in this Demonſtration, Firſt, becauſe the weight B is more eaſily moved; he concludes alſo, that it hath greater force to move the oppoſite weight, but whether he hath aſſigned the true cauſe, the comparing of the cauſe with the effect will ſhew; which that we may conſider, we ſuppoſe the line A B to be double the diameter A C, therefore G C will not be double of the line F B, therefore will not the preternatural mixt motion in the weight C, be double to the preternatural mixt motion in the weight B, and therefore that cauſe is not moſt likely and true from whoſe Compariſon the proportion of the effect and cauſe is not ſhown: For it is certain, that the weight of 1 pound in the point B will be equivalent to the weight of 2 pound placed in the point C or T; Whence we deny this concluſion can follow from that antecedent, that the weight which is fartheſt diſtant is eaſieſt moved, therefore if it be diſtant a double diſtance, it will obtain a force doubley greater; and neither do *Mathematicians* deduce their concluſions after that manner; although while the diſtance increaſes the facility to motion ſhould increaſe, it doth not follow that it increaſes in the ſame reaſon or proportion: And ſo we deny the facility to motion of the weight in B to be double, to the facility to motion which the weight hath in C; becauſe that contrary which is mixt in C is not double to the contrary which is found in B.

Secondly, *Ariſtotle* ſpeaks of the ſwiftneſs of *Motion*, and from the Swiftneſs he concludes to the *Power* moving, which we ſhall ſhew to be falſe. It is certain, that if two Weights ſhould be ſucceſſively in the point B, one of one pound, and the other of two; nevertheleſs they will be equally or with

equal

equal velocity moved downwards, if they are of the ſame matter and figure, or if there be found ſome difference, it will not be in proportion to the weights; Wherefore although we ſhould grant the weight B to be moved with a velocity double to C, yet notwithſtanding the force of his reaſoning doth not conclude it to have greater force to move the other.

Thirdly, what is ſaid in demonſtrating the weight B to be moved with a double velocity or ſwiftneſs to C; he either underſtands while they are joined in the ſame ballance, or he underſtands it while they are ſeperate and in two ballances: If he means the firſt, there was no need of ſo much reaſoning, neither doth that preternatural mixt motion help any thing. But if theſe two weights are lookt upon as Seperate, or in divers ballances, that we may examine what force they have, it is falſs that that which is fartheſt diſtant, is moved with a double Swiftneſs. *Ariſtotle* knew not the doctrine of *Pendulums*, for the ſwinging of divers *Pendulums* are perform'd in equal time, to wit, if in the ſame time that the weight B being left to its own nature comes to L, in the ſame time the weight C will come to D, alſo they abſolve each his quadrant in the ſame time; Notwithſtanding if there be two pendulums C and B, and the Swinging of the weight B be longer than the ſwinging of the weight C, ſo that if the leſſer dure 2 minutes, the other weight B takes up almoſt 3 minutes in perfecting its vibration; Whence howſoever he explicates this Demonſtration, he wavers in all things, and is far from *Mathematical* conviction. Moreover we will ſhew, that although the demonſtration have ſome force in that part of the Circle, yet it obtains none in others; for in the firſt place let the lines O H, Y K be equal, and draw the parallel lines K R, O P; It is certain, that O P is greater than K R, therefore if there be a weight in R and another in P, one deſcends in Y and the other in H, the preternatural motion will be more in the weight more remote, notwithſtanding in this caſe the weight which is at greater diſtance, obtains greater force; therefore that which hath greater force, is not begat from the leſſer mixture of preternatural motion; which may better be perceived in the points 3 and S; for if the weight 3 move to S, and the weight X to T; the lines V T, S Z meaſure the preternatural motion, and the lines V X, Z 3 the natural motion, and the weight X leaſt diſtant from the centre or *Beam*, will be more moved by the natural motion than

the weight 3, and therefore easier, whence it obtains greater force.

Whoso diligently considers the parts of each quadrant, will find this mixture of contrary or preternatural motion to be less in the lesser circle than in the greater; and the reason is, because although towards the Diameter A B the greater Circle comes nearer to a vertical line, yet towards the diameter R H it comes nearer to an horizontal line; and so much for the first part of this Proposition.

Fig 9. That which belongs to the second part of the same Proposition, to wit, although we grant that, which *Aristotle* assigns for the true cause, why in the ballance the weight most distant from the centre hath greatest force, to wit, that it hath less of the contrary or preternatural motion, yet notwithstanding we do not find the reason to be the same for the *Leaver*. For the power A, may move Circularly, so that it have nothing of Preternatural motion, since the power of an *Animal* is indifferent to any different place; therefore since it hath no preternatural motion admixt, the force of the greater Circle doth not move easier than the lesser, which notwithstanding is contrary to all experience.

Secondly, that kind of *Leaver* only in which the *Prop* or *Hypomoclion* is found between the *Power* and the *Weight*, may properly be reduced to the Ballance, but the other kinds not so properly.

Thirdly there are divers *Machines* or *Engins* which are difficult to reduce to the *Leaver*, and by that means to the *Ballance*; and first for the *Wedge*, We ask whether there be a *Prop* or *Hypomoclion*, and to what kind of *Leaver* it is reduced? What Circle is described from it? What is its preternatural motion? What its natural motion? Surely there is in the *Wedge* the impression of the weights resistance to be exercised in the parts in which the body touches, as in K R; We ask in what point is the *Prop*? Where the length of the *Leaver*, Which if it be increased according to the common rules of the *Leaver* the Virtue of the Power will be increast? If 'tis said the point of it is the *Prop*, we will shew 'tis not, because if the point of the *Wedge* should be cut off, yet nevertheless the *Wedge* would have its whole force; If 'tis said the line K L is the length of the *Leaver*, 'tis falss, because although that length be cut shorter, yet notwithstanding the virtue of dividing is not deminisht which is in

in the *Wedge*, therefore which way ſoever you turn the *Wedge*, you will ſcarce reduce it to the *Leaver*.

Fourthly, Much leſs do we own the compariſon of the Leaver in Screws, which may rather be reduced to the Wedge; for if you own the Axis of the Cylinder, about which the ſcrew or ſpire is circumvolved to be the *Hypomoclion*. The diſtance of the Spires or Screws from that Axis, will be the diſtance of the weight from the *Hypomoclion*, according to which diſtance the reſiſting power of the Weight is meaſured, whence it follows in the Screw, the Cylinder that is leſs than the other pairs, more eaſily overcomes the reſiſtance of Weight, which nevertheleſs is falſe: For neither is this the meaſure of the reſiſtance of the Weight, or the virtue exiſting in the Screw, but ought to be deduced from other principles, to wit, from the compreſſion of the Spires, for when the Spires or Helices are more thick or cloſer together, the ſtronger and more powerful are the Screws; Therefore we muſt ſeek another principle of *Machines* or *Engins* more clear and eaſie, which being once conſtituted, the power of every *Machine* or *Engine* well be unfolded, and the proportion of it to the reſiſting force of the Weight will be detected.

PROPOS. III.

Archimedes *reaſon Examined.*

Fig. 10. ARchimedes in his ſixth Propoſition, *Æquiponderantium*, and many others after him, have attempted to eſtabliſh as the chief principle of Machines or Engins, that in the Ballance, if the weights and their diſtance from the Centre be reciprocal, they conſiſt and counterpoiſe each other.

In the firſt place, we referr this to be ſettled by the reverend Father [*Leotanudus*,] and what power his demonſtration may obtain; ſuppoſe A B to be a Rod of a like weight in every part, and divided in the middle in C, and underſtand C to be the Centre of Gravity, and C D to be drawn through perpendicular to it; by the point D draw an iron rod D E, which let be ſo alike for weight as to conſider it wanting all weight, and

let D E be greater than the half of C B, and make G D equal to I B, and H K equal to the line A H; when the lines C I and I B (equal to H C) are added, H I and C B will be equal, and so H I will be equal to the half C B, and the remains A H, I B together are equal to the other half; and because A H, H K are equal, being taken from the two equal aggregates H K, K I, A H, I B, the lines K I, I B will be equal. Let two Threds or Lines H G, I E hang up the rod A B, and fasten it to the rod G E in the point D, which answers the Centre of gravity C, the line from whence 'tis hung up being perpendicular with the line D C, answers to the Centre of gravity C; A B will remain equally poised, or in *Equilibrio*.

The Demonstration. Let the Rod A B be really divided in the point K, that is, seperate the Union, or cut it in two. First, since A H, H K are equal, neither will preponderate or out weigh the other; moreover since K I, I B are equal, neither will prevail, wherefore as yet they will remain in *Equilibrio*; therefore the whole line will remain in the same manner as before, being hung by the same point D, therefore as yet the whole line will be in *Equilibrio*: But so is the distance H C of the weight A K from the Centre, to C I the distance of the lesser weight K B from the same Centre, as the weight K B to the weight A K; for so is A K to K B, as its half H K or C I is to K I, or H C its equal; therefore we have this in *Equilibrio* while the whole weight A K is to the weight K B, as the distance I C to the distance H C reciprocally, which was to be demonstrated.

We will consider hereafter whether this Demonstration convinces, and assumes nothing as now proved, which notwithstanding should be demonstrated.

Fig. 11. *Archimedes* a little after endeavours to prove this somewhat otherwise, and he supposes the Iron Rod to be A B, and he substracts from its gravity that which is hung in the middle point G; he hangs 6 equal weights, here 3 and there 3 at equal distances, 'tis clear that they are in *Equilibrio*, he supposeth also that all these weights are alike, and equidistant between themselves: Also he supposes any weights to gravitate and operate in the same manner, as long as they retain the same common centre of gravity.

The Demonstration is clear, in case the weights be distributed according to the disposition unfolded, before which common

mon centre of gravity of all the weights together will be in G; but if you consider 4 weights B C D E whose centre of gravity will be in the point I, and the centre of gravity of the weight F L is in H; wherefore the weights will gravitate in the same manner, howsoever they are disposed, they keep in a manner their centre of gravity in the same point H; therefore conjoin the weights F and L in the point H, and conjoin the 4 weights B C D E in the point I, or so about the point I, that their centre of gravity may be the point I.

Fig. 11. All these weights will gravitate in the same manner in this disposition, as in the former; But in the former they were in *Equilibro*, therefore in this second disposition they will be in *Equilibro*: But in the second case, so is the weight BCDE to the weight F L, as the distance G H to the distance G I therefore it will be in *Equilibro*, when as weight is to weight, so is distance to distance reciprocally.

These Demonstrations are ingenious, but they do but suppose those things to be the principles of *Engins* which is sought: For first of all in both Demonstrations he mentions the centre of gravity, but it is not known what that centre is, and this centre of gravity can hardly be proved, unless there be constituted a common principle of *Engins*; In the first, although it seems clear enough that the division being made in the point K, the lines A K, K B lie in a direct line, because that both parts A H, H K and K I, I B are equal; Notwithstanding it doth not appear to me that they ponderate in the same manner, the division being made as before: For the part C K before the division, exercised its gravity with the other part K B, and as I may say, was staid by its parts: But the *Union* being loosed, it exercises now its own gravitation, together with the other part A C; Whence although it were before in *Equilibrio*, it follows not that it being seperated the *Equilibrium* remains.

I say the same of *Archimede*'s demonstration, for I cannot grant that weights have the same manner of gravitations they should have among themselves, and the same gravitation they should have respectively to another weight, so often as they change not the proper centre of gravity: If in one case, one of them will be found on one part of the centre, and in the other it will decline to the other part; that is, 'tis doubted whether the weight E transported in I being united with other weights B C D in

D in the ſame point I, hath the ſame force, and not greater, or leſſer.

And that we may ſhew the Principle ſought, the definition of the Centre of gravity is commonly thus given, to wit, 'tis the point dividing the heavy body in two parts of equal moments, but moment is not ſimply the weight of body, but grows together from the weight and diſtance, therefore to the underſtanding of the Centre of gravity the conſtituted principle is ſuppoſed, whoſe reaſon we ſeek; *viz.* Why weights by reaſon of their greater diſtance from the centre have alſo greater force to move.

PROPOS. IIII

The true Reaſon of increaſing power by Engins.

Fig. 12. NOne will require of us a ſtrict demonſtration here, becauſe we are buſied in phiſick matter, and we inquire the principal of natural and ſenſible motion, which perhaps will not preſently occur; one thing I muſt ſay, that although I do not effect the thing, yet by removing things out of the way, I ſhall open a door to let into it; therefore I ſhall attempt many methods, that ſo if one arrive not at it, I may make way for another: Firſt, in the ballance I will endeavour to ſettle that common maxim, while the weights and diſtances from the Centre are reciprocal it is in *Equilibro*; As if in the ballance A B the weight A of two pound is to the weight B of one pound, as the diſtance C B of two feet to the diſtance A C of one foot. If from a piece of timber, you hang a ballance from the point C, to be in *Equilibrio*, ſo that you remove it ſo far from the Centre to anſwer the addition that ſhould be made to the weight, that is, if the weight of one pound hang in the point D, and in A a weight of 2 pound, to make them in *Equilibro* the ſame weight ſhould be added, and in ſtead of the ſame weight you may add the ſame diſtance, or ſo remove it from the Centre that C B be double to CD; Thus a weight of 1 poundbeing placed in B, it will be again in *Equilibra*, experience ſhews this, but the reaſon is to be ſought.

First,

First, I ſuppoſe any heavy body to reſiſt a motion upward; and the greater it is, the greater motion it will reſiſt; ſo that a greater violence or force is required to move upwards a weight of 1 pound the ſpace of two feet, than to raiſe the ſame weight but one foot high, or at leaſt it requires a force to be applied of a longer continuance of time.

Secondly, I ſuppoſe while the weight is moved downward, the weight on the other part of it may move ſomewhat upward, ſo that it may overcome the reſiſtance which the oppoſite weight hath to motion upward; alſo while a weight is moved more down or lower, it produces a greater *Impetus*, together with that motion which would have bin if the motion had bin leſs; this laſt part of the ſuppoſition ſeems hard, therefore I ſhall explain it more largly.

I Suppoſe thirdly ſome productive cauſe of motion to be given, diſtinct for the moſt part from the principal agent to which motion is aſcribed, as in things projected or caſt from one, I think in good *Philoſophy* it can ſcarcely be denied, ſuch like cauſe beſides motion which is ſucceſſive, and no part whereof exiſts with the other, and therefore the other cannot be the cauſe, for every effective cauſe acteth not but when it exiſts; Therefore while its action exiſts, it ſelf alſo exiſts, and while its action exiſts the effect exiſts by ſuch action produced: Therefore while any effect is produced and exiſts, its cauſe exiſts, but while one part of motion exiſts, another part exiſteth not, therefore one part of motion cannot be produced from another, and therefore another cauſe of motion ought to be admitted, but this cauſe is not the principal agent to which motion is attributed, for firſt in things projected, the hand which throws the ſtone is not any more join'd with the ſtone in conveying it through the air, and therefore produces nothing further, neither can that be attributed to air that ſome do, to wit, that the hand while it Impels the Stone, impels likewiſe the contiguous air, and that air other air, untill it make a Circulation, and this laſt air carries the Stone farther; but on the contrary, in the ſame preciſe Moment and time wherein the Stone joined to the hand moves the air juſt before it; (ſince Penetration is not granted) in the ſame time alſo this air moves the following air, and ſo conſequently makes the whole Circulation at the ſame preciſe time, and there is found only the priority of dependence. Suppoſe the motion of the Stone to be from the

point-

point A to B, and in the same precise time it makes the whole Circulation, and the air which was in E follows in F, neither hath it greater force to farther motion than it hath from the Stone; from the following time I ask whether the motion of the air F depends on the motion of the Stone, or the motion of the Stone on the motion of the air, if you say the first, I demand again from whence the Stone is moved, if the second, I ask from whence the air is moved, for the past motion of the stone cannot be the cause of motion of the present air, therefore it is necessary to say something is added to the Stone from whence it is carried through the air, and this I call *Impetus*, or force, whatsoever it be.

Moreover I will shew, *Impetus* being granted, *viz.* While a body descends it seems to me a reason to be alledged, why in the first space of time the body descends one foot, in the second three, in the third five, in the fourth seven, and so on, unless the continual production of some *Impetus* be admitted, which is the immediate productive cause of motion, which *Impetus* is permanent and may be increased.

Also it follows, that a second *Impetus* is not produced, unless the first hath and produces some motion, let two weights be suspended in the air, each produces some *Impetus* in it self, and also in the body which they hang on, let one weight be moved by the space of three instantes, or moments, so that after that third instant it hath an *Impetus* as three, let down the second weight in the begining of the fourth Instant, wherefore it hath not the *Impetus* as three as the other weight; because (you'l say) it remains unmoved, and the other is moved: therefore motion is the condition to the producing a farther *Impetus*, at least such motion whose *Impetus* is according to nature.

Which I shall likewise make good from other experiments: First, why while I drive a nail with a hammer of a longer handle I produce a stronger blow, or stroak, in like manner, if I lift the arm and the hammer higher, so that it describes a greater circle, the stroak is made more valid and strong; no other reason can be given, but that by the greater motion (whether as the condition, or as the cause, it matters not) a stronger *Impetus* is produced, so that the power unless it be moved, never produces in the begining of its motion such *Impetus* in the nail, how great soever the endeavour be, as it produces

produces while it hath ſome motion; ſo that if 10 men preſs with their weight upon a nail it doth not enter the wood ſo well, as if it be drove with an hammer by one man.

While any one runs a pace, if his feet be ſtopt he cannot chuſe but fall; and ſo a horſe on full ſpeed can ſcarce be held in, whence they lift up their fore feet, as it were a contrary motion to aſwage every concieved *Impetus*; While a boat is carried with a great *Impetus*, and is ſuddenly ſtopt at the ſhoar, all that are in the boat are moved, becauſe now the concieved *Impetus* is conveyed farther they bend forward being ſtopt.

And I ſhall ſhew that a weight of one pound placed a little farther from the Centre than another weight of one pound, will raiſe it up; ſuppoſe two weights equal each to one pound, ſo placed in a ballance that one is double the diſtance of the other from the Centre; whence I thus argue.

The weight of 1 pound while it moves downward 2 feet, may over come the reſiſtance which a weight of one pound hath to motion upwards one foot: therefore if they are ſo fitted in the ballance, that while one is depreſſed 2 feet, the other is only raiſed 1 foot, it raiſes that upward; The antecedent is proved, while the weight of one pound is moved downwards 2 feet, its active force or *Impetus* which it puts forth together with ſuch motion, is preciſely equal to that reſiſtance which the oppoſite and equal weight hath to motion upwards two feet, but the reſiſtance to motion upwards one foot is leſs than to motion upwards two feet; therefore while one pound weight is moved downwards 2 feet, the other pound weight may be moved upward one foot; But when two equal weights are ſo placed in a ballance, that one is doubly diſtant from the Centre to the other, it alſo effects a double ſpace to that which its oppoſite effects; therefore we have one reaſon now, why between equal weights that which is fartheſt diſtant from the Centre is depreſſed, and raiſes up its oppoſite weight, which may be alſo proved in this manner; when two unequal weights are equally diſtant from the Centre the greater raiſes the leſſer, becauſe the parts of motion downwards are more than thoſe upwards, and in like manner when equal weights are ſo placed in a ballance, that one is farther diſtant from the Centre than t'other, the parts of motion downwards will be more in one than the parts of motion

upwards, are in the other (or its opposite) therefore the weight which is farthest distant from the Centre will raise the other opposite being equal to its self.

The motion upwards of heavy things is against nature, and the violent motion of them downwards is agreeable to nature; but how much that is which is against nature, so much is the resistance to that; and how much that is which is agreeable to nature, so much is its inclination and active force to overcome the opposite resistance; therefore where there is a greater motion downwards than the motion upwards, the active force of resisting will overcome.

The second reason is; a greater *Impetus* is required to move the same weight a greater space than a less, whether the whole *Impetus* be produced together, as happens in things projected or thrown; or successively, as when a weight is drawn.

Also a greater *Impetus* is required to move a greater weight some space, than to move a less weight the same space; whence I thus argue, an *Impetus* which is required to move a weight of two pound one foot, is double to the *Impetus* which is required to move one pound one foot; But the *Impetus* which is required to move one pound, two feet, is in like manner double to that which is required to move one pound one foot; therefore the *Impetus* which is required to move two pounds one foot, is equal to the *Impetus* necessary to move one pound two feet, for those same things which are doubled are equal among themselves: But when two weights are so placed in a ballance that the weight of two pound is distant from the centre one foot, and the weight of 1 pound is distant two feet; while the weight of 1 pound is moved downwards two feet, the weight of two pound is elevated one foot; and one pound weight as moving downwards two feet is in *Equilibrio* with one pound moving upwards two feet: Therefore one pound moving 2 feet, will be in *Equilibrio* with 2 pound moving upward 1 foot.

And that we may render the same reason more universal, and that we may apply it not only to weights and ballances, but that we may extend it to all *Engins* in general. Suppose as before, by how much more the power is that is moved, by so much the greater and stronger is the *Impetus* produced; therefore if a power while it is moved 1 foot can move 100 pound 1 foot; while the same power is moved two feet it will move

200 pound 1 foot; to clear which point, suppose for explication sake a certain opinion rejected by most *Philosophers*, to wit, that time increases or grows from indivisible Instants succeeding each other; suppose likewise that which necessarily follows from such an opinion, to wit, the slowness of motion is posited in more or less little Staies of rest, which opinion I do not propose that in it I may found my reason, but only that I may shun that confusion which the common sentence begets, concerning the continued composition from parts infinitely divisible; for when they treat of this infinity, 'tis no wonder if they mix obscurity and darkness together; Therefore suppose a power which while it is moved one point may move 100 pound one point, and being fitted in an *Engin* so that while the power is moved two points, the weight is moved only one point.

In such a supposition, the power will be moved the space of one point, the weight all the while no ways resisting such a motion, because the weight as yet is at rest, but when the power is moved to the second point, it hath a double *Impetus*, *viz.* the *Impetus* produced in the mean time while it is moved through those two points, but a double *Impetus* moves a double weight; therefore the power which is moved two points will move a double weight one point, if it be so fitted in an *Engin* that necessarily its motion ought to be double to that which follows in the weight.

And although this opinion Concerning continuals shouldnot be true, and the power should never be moved but the weight should be moved although slowly; nevertheless since a power exerts a greater *Impetus* when it is most moved; as often as the motion is greater in it than in the weight, so often the *Impetus* will be greater in it, than if it had bin moved equally with the weight; but a greater *Impetus* can overcome a greater weight, therefore a greater motion of a power compared with a lesser motion of a weight can allso overcome a greater weight.

To make it clearer, Suppose, to move a weight of 100 pound one foot, an *Impetus* be required as 4, which the power A may produce, and as I may so say, to lift it up while it is moved one foot; there will be required to move a weight of 200 pound one foot, an *Impetus* as 8, but an *Impetus* as 8 is produced from a power if it be moved 2 feet; For more *Impetus* is produeed from a power while 'tis moved two feet than while

'tis moved one foot, therefore that principle remains, *viz.* The Power as moved 2 feet effects the same, as two powers which are moved only 1 foot; and we must not think *Impetus* to be so fluent of nature, as not to maintain and as it were heap together, that is, if the power be moved for some time it should not increase, also its intensive *Impetus* is not resisted by such *Impetus*; in like manner, a weight is not supposed so to resist a lesser motion, as a greater; whence if a power be so compared with a weight, that while it is moved 1 foot the weight is necessarily moved the same, and the resistance of the weight is greater as moving one foot than the *Impetus* which is produced from the power being moved 1 foot, no motion follows; but if an *Engin* thus distributes the same *Impetus*, that the whole be Imployed in moving the same weight half a foot it will make some motion.

Neverthelesss because this thing is of so great moment, and contains the most universal Principle in nature, therefore 'tis worth our while to prosecute the thing a little farther, and to apply it in every part that it may appear more plainly.

I suppose first, that 'tis equivalently the same thing to apply a motive power as one, successively to move a body, suppose the space of 5 feet, so that it move in the first time the space of 1 foot, moreover the same power moveth in the second time by another, and so on, and to apply five moving Powers Successively as one; of which, to wit, the first moves in the first time 1 foot, the second in the second time following, the third by the third, and so on; for the moving power as one if it be applied to the second time, may as well move another also like it self, therefore the same will be Equivalent whether the same motion continue, or another like to it be Substituted.

Secondly I suppose to move or sustain a body, to be the same, as to apply five powers each of which is a power as 1, and to apply 1 so that it may be a power as 5, as if in one ballance you put a body of Gold of one foot, the same will out weigh 5 bodies of each 1 foot of another matter, which is five times lighter than Gold, for neither hath the moving virtue in it self, as the first quality; for if 5 heats or warm things are put as 1, they can never be produced in the Subject but as one heat: But and if 2 Powers are sufficient to move each of them a weight of 100 pound, If they are joyn'd and concur

concur together they will overcome or move a weight of 200 pounds; This rule is common in all Equivocal Agents, so if the powers of two candles in some determinate place, each of them produces 1 degree of light acting together in the same place they produce a greater degree of light; so while the Sun in an Eclipse is hid in some parts, the light Shineth more weakly, therefore in these cases extension begets intension,or is equivalent to it.

Suppose two men move unequally, to wit, with a double velocity one to the other; what is in one that is not in the other; And first it is certain that the motion of the one is always double to the other, so that while one is moved one foot, the other only moves half a foot; and while the first passes over half a foot, the other passes over a quarter of a foot; and in whatsoever time assignable, the parts of motion in the one are more than in the other, whence 'tis certain in the second place, if the motion of the power confers to this that it move the opposite weight, while the power hath greater motion it produces a greater *Impetus* in the opposite weight, from whence the argument may be formed.

A power advances its force by motion, therefore while 'tis moved with a double velocity, 'tis equivalent to a double force, but a double virtue or force can move a weight doubly greater, or as great again, therefore a power moved with a double velocity can move a weight doubly greater; the first Antecedent is certain, for a power however it be applied will not move unless it be moved, whether its motion be the condition to this that moves, or whether the motion it self be the immediate cause of motion,it matters not; neither is there need to examin these things, since divers explications arise from divers phisical principles: For some acknowledge no motion which takes not its rise from *Impetus* or force, and consequently to produce a greater motion in a power, they require a more stronger *Impetus*; therefore if a power be moved with a velocity double to the weight, it produces an *Impetus* doubly stronger to that which it would have had if it had bin moved equally with the weight: But if it be moved equally with the weight, the *Impetus* which is produced in it self should be sufficient to move 100 pound such a space; therefore if it be moved with a double velocity it will move 200 pound the same space; being explained, we'll Suppose a free Power to impel lightly some weight,

weight, so that by the force of its impression it is not moved, it will use a greater endeavour and at length moves it. I ask what makes that greater endeavour unless a more stronger *Impetus* be produced (supposing always that such *Impetus* is granted) but if the power it self be moved more swiftly, it produces a greater *Impetus* : Therefore by the greater motion of a power is adhibited that which is necessary, that a weight may be moved doubly greater (or as great again) each part is proved, to wit, while any body is moved more swiftly a stronger *Impetus* is produced; or the intense motion being Secluded what way soever from *Impetus*, the succession of so much local motion is agreeable with intension; For the velocity of motion is some perfection which cannot be explicated, because of the succession of motion, and the infinite divisibility of time. Notwithstanding in each opinion, velocity or Swiftness is said to be some perfection of motion : For suppose in *Fig.* 14 some motion in Angles, in as much as some think them indivissible, let A B C D a potent angle in one instant also indivissible be so moved, that leaving the former space A B C D it possesses the next following C D E F, Suppose another angle or as some call it, a Physical point G H K I be so moved, in the same indivissible instant, that leaving the former-space G H K I it possesses the space L M O N, Surely the former motion is a more perfect motion than the second, and therefore if there be required an *Impetus* to motion, there is required a more stronger to effect the first motion than the second : But if no *Impetus* be required, but immediately motion be produced from the power, there is required a far stronger endeavour to obtain the former than the latter ; Wherefore to conclude the greater endeavour of Power moveth a greater weight than a lesser but a greater endeavour of power is advanced while 'tis moved swiftly than while slowly, therefore while a power is moved swiftly, it also moves a greater weight.

Also the first consequent is plain, to wit, (while a power is moved with a double velocity 'tis equivalent to a double power) for sure it is, while any power adhibits or uses an endeavour doubly greater, 'tis equivalent to two powers each adhibitting or using an endeavour doubly lesser. So one horse if he endeavours much, may draw a determined weight, which he may draw twice as easy, and without so great endeavour, if another horse be joined with him to assist. Wherefore if it be moved

moved more ſwiftly it will be equivalent in order to move a weight of a greater force, although ſomtimes the weight doth not increaſe its motion; for if the motion of the power be increaſed, the motion of the weight is equally increaſt. A power moved more ſwift will indeed be equivalent to a greater, but all that perfection which happens to it from motion relates to the making the motion of the weight greater, for a weight of a greater motion reſiſteth more, therefore in motion theſe two are always taken for the ſame, to wit, to move a greater weight to a leſs ſpace, and a leſs weight to a greater ſpace; for as to move a greater weight a greater endeavour is required, ſo to move a weight to a greater ſpace, a greater endeavour is alſo required, The whole artifice of Engins then conſiſts in comparing the greater motion of the Power with the leſſer motion of the weight, and according to the proportion of exceſs the Force of the Powers are increaſt; becauſe powers increaſe not their force but by motion, and therefore motion doubly ſwifter, produces *Impetus* doubly greater.

PROPOS. V.

Moveable bodies are equal in force whoſe Magnitudes *and Velocities are reciprocal.*

IT is certain, that the ſame body moved with unequal ſwiftneſs, will have unequal force; alſo a greater body moved with the ſame ſwiftneſs as a leſſer, will have greater force; and we ſee likewiſe in Engins that weights may be ſo diſpoſed from one place to another, that the motion which is made from one hath the ſame proportion to the motion of another; and alſo that weight to weight is made reciprocally in *Equilibro*, ſo that the double celerity or ſwiftneſs of one pound, will be equivalent to the Subduple celerity of two pounds; We may alſo transfer the ſame principle to other moveable bodies, although they are at liberty, that is not being diſpoſed in any *Engin*: For it hath not leſs force when it is free and looſed from *Machines* or *Engines* than when it is faſtned to ſome Body,

but

but 1 pound with the velocity as 2, is equivalent to 2 pounds having the velocity as one: Therefore alſo without an *Engin*, a moveable body as 1 with a velocity as 2, will effect the ſame as a moveable body as two with a velocity as 1. The reaſon is, becauſe the motion or degree of velocity is the ſame in both, in a greater body they are fewer in each part; in a leſſer more. Neither is there any other reaſon, why while they are joined in *Engins* they are of equal force,and one extenſion compenſates another, and without an *Engin* the ſame will not happen.

Wherfore the moments or forces of equal bodies, or the parts moved are to one another, as their velocities; and equal velocity, as the magnitude of bodies; for commonly, moment and force, and parts moved, ſignifie the ſame, except ſometimes moment likewiſe is attributed to bodies at reſt, which have notwithſtanding an aptitude to motion, wherefore what we ſhall ſay concerning moments may be ſaid of forces.

If 2 unequal moved bodies be compared, their force or moved parts will be in proportion compounded of the proportions of the bodies, and of their velocities, becauſe every part of a body is ſuppoſed to be moved with the ſame velocity, or degree of force; whence it happens, if the motion of one body be communicated to another equally, the velocity will be equal, if the velocities of the greater and the magnitudes of the bodies be reciprocal.

Whence we conclude,if a moved body runs againſt another body at reſt all reflexion being excluded, to wit, if each body be ſoft, they proceed together, and the velocity of the former will be to the velocity of the aggregate of the whole, as the whole aggregate to the firſt movent reciprocally; For ſince in the former there are ſo many degrees or parts of motion, and each of its parts are diſtributed in the aggregate; to get the velocity of the firſt movent, the quantity of motion which is always the ſame muſt be divided by the number of parts of the aggregate; Therefore the ſame number of parts of motion is generated from the aggregate; in its velocity, as from the firſt movent in its velocity. Therefore if you diſpoſe the aggregate, the firſt movent, the velocity of the firſt movent, and the velocity of the aggregate, ſince the rectangle of the firſt and the laſt is equal to the rectangle made of the 2 means; ſo will the aggregate be to the firſt movent, as the velocity of the firſt movent to the velocity of the aggregate.

We

We must reason after the same manner in other cases which may happen; as if there be two equal movents)or bodies moved) which are born in the same part,one hath the velocity as 4, the other as 8, and the more Swift incurs or meets in the less Swift; I say after the meeting, the velocity of the Aggregate is as *6*; for since the Bodies are equal, the parts moved will be as the velocities 8 and 4; wherefore the motion in them will be as 12: but after the meeting the parts moved ought to be the same so many, therefore the motion in the whole aggregate will be as 12, and in each body as *6*; therefore the velocity of the least, before their meeting was 4 and afterwards *6*; and of the greater 8 and after meeting but *6*.

Thirdly, if two equal bodies with equal velocities meet each other, excluding all reflexion, they will rest, because these velocities meeting one another, destroy each other, as when you put contrary qualities in the same Subject.

Fourthly, if 2 unequal bodies, suppose 2 globes one of one pound weight and the other of 2 pound, meet each other directly with equal velocities, suppose as 4, the Aggregate follows the direction of the greater, and the velocity will be as 1 $\frac{1}{3}$, for the quantity of motion in the greater is as 8, in the lesser as 4, while they meet each other the motion of the less as 4 detracts so much from the greater, therefore the quantity of motion remaining is as 4, to be divided by 3 pounds, there will be in each pound, one degree and $\frac{1}{3}$.

Fifthly, if two equal bodies with unequal velocities meet each other, suppose one hath velocity as 2 the other as 4; after meeting, Secluding reflection, the quantity of motion remaining will be as 2, each being divided, and therefore the aggregate will be moved as 1.

Sixthly,Suppose two unequal bodies one whereof is one pound, and is moved with a velocity as 3: and the other is 2 pound,and hath a velocity as 4; the quantity of motion in the first is 3, In the second 10, for when they meet, the lesser quantity destroys so many degrees of t'other as it contains it self, therefore, there remains 7 to be divided by 3 pound: Wherefore in the whole aggregate there will be 2 degrees and $\frac{1}{3}$ of velocity.

Fig. 15. If 2 unequal Bodies be placed in two equal Branches or Arms of a Beam (as a pair of Scales) I say the velocity of the greater only will be to the velocity of the aggregate, as the aggregate to the greater weight. Suppose a

weight of two pounds, which if it be moved alone from A in B with a velocity as 4. Put on the other part a moveable body as 1; which suppose to move downwards with the same velocity: And these weights being compared as two meeting each other with equal velocity, wherefore since the quantity of motion in the greater is 8 degrees, and in the second 4, and supposing them contrary to each other; the motion in the aggregate remaining is as 4 to be divided by 3; the velocity therefore in each will be as $1\frac{1}{3}$.

If there should be 2 equal *Pendulums* placed in two unequal Branches, the manner of reasoning will be the same. Suppose then the weights A and C to be equal, but the distance AD to be double the distance DC; in such disposition the velocity of the weight A will be double the velocity of the weight C, wherefore the quantity of motion in A will be double: Suppose the motion in A as 8, in C as 4, which motion since 'tis contrary destroys from the motion of the weight A, 4 parts, therefore there remains 4 parts to be divided, so that that of the weight A have 2 parts, and that of the weight C, 1 part, Therefore there are in A 2 parts and $\frac{2}{3}$; and in C 1 part and $\frac{1}{3}$.

PROPOS. VI.

Concerning the Proportion of weights, on the ends of the Arms of a Ballance, Variously placed from the Horizontal *line.*

Fig. 16. THe proportion of a weight in C to the same weight in F, will be as the whole Arm BC, to its part B *u*, being placed between the Centre and the line of inclination F *u* M, which the weight freely makes from the extream F towards the Centre of the world. For the better understanding whereof, suppose on the other Arm of the ballance B D, and in the extream D, a weight placed being less in weight than C, as B *u* part of BC which is less than B D, It is clear from the 6 Proposition of the 1 book of *Archimedes* of weights, that if in the point *u* you place the same weight C, the ballance

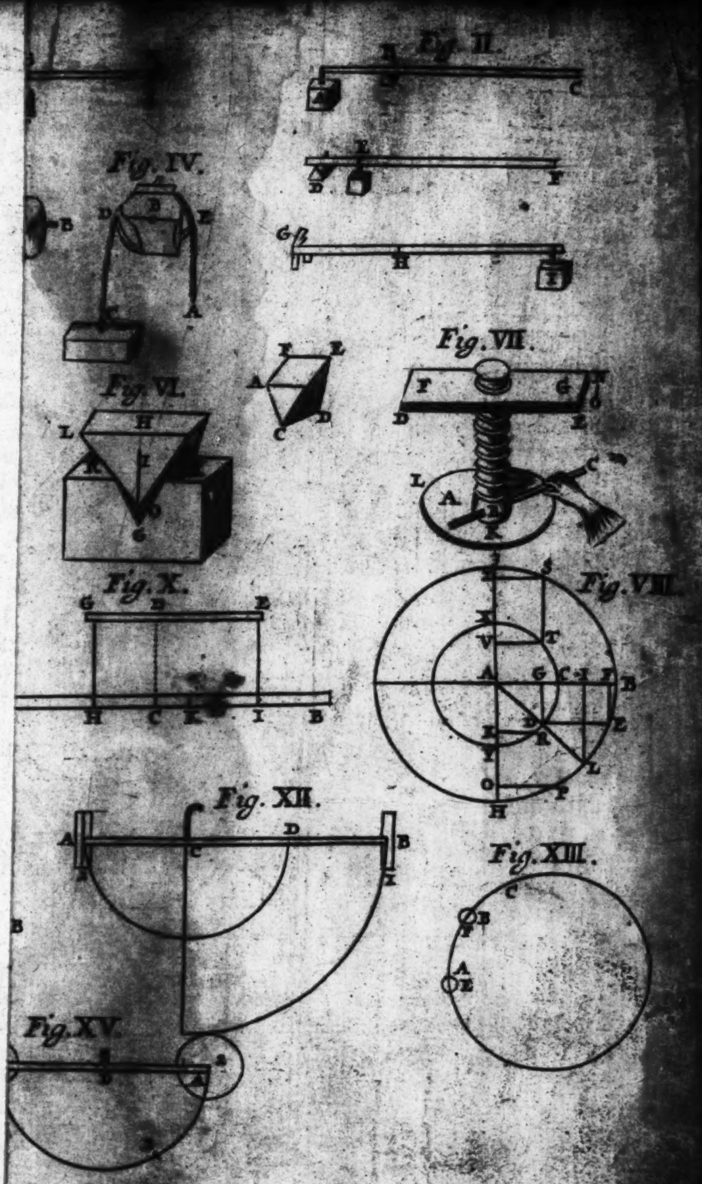
Fig. II.
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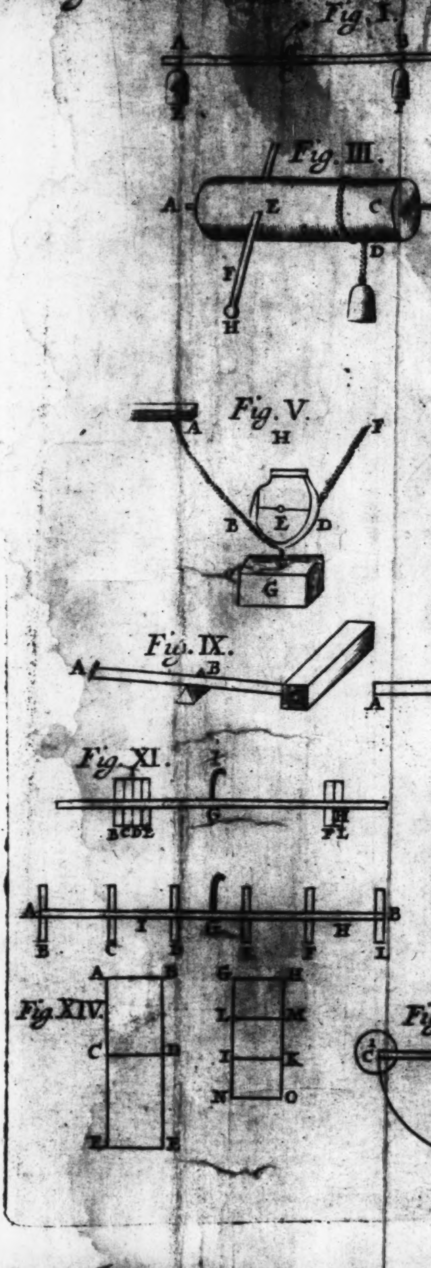

ig. I.

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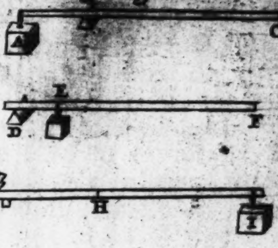

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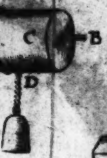

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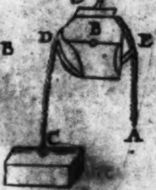

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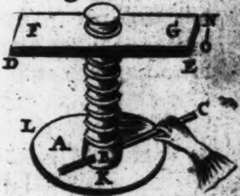

Fig. VI.

Fig. VIII.

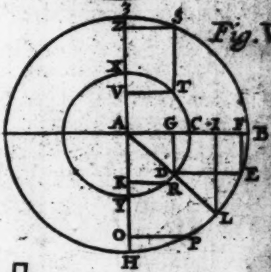

Fig. X.

Fig. XII.

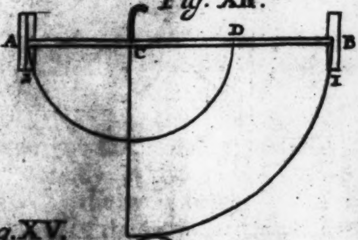

Fig. XIII.

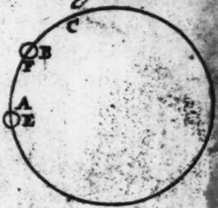

Fig. XV.

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lance will little or nothing be moved from the *Horizontal* position. But if the weight F equal to C be placed in the extream F of the arm B F; it is the ſame as if it be placed in *u* of the Horizontal line B *u*: To the better underſtanding whereof, Imagin a perpendicular thred F *u*, and in its extream *u*, the weight to hang which was at F, whence it clearly appears that it begets the ſame effect as when it was in F; which as I ſaid but now remaining fixt in the point *u* of the arm B *u*, it is ſo much lighter than when it was in C, as *u* B is leſs than B C. I ſay the ſame, if the arm be poſſited in *e* B, which we may eaſily try if we hang thred from *u* of the arm B C perpendicular to *e*, in which extream hang a weight equal to the weight C and at liberty from *e* of the Arm B *e*, whence the ballance will remain *Horizontal*. But if the arm B e be joyned in ſuch ſite with the *Horizontal* B D, and the weight C be hung in *e* freely from a thred, it will neither aſcend nor deſcend, which is only becauſe it is hung by a thred which hangs as much from *u*, as that which is hanged freely from *e* of the arm B *e*; and this proceeds from this, becauſe it partly hangs from the Centre B: And if the Arm or Beam ſhould be in the ſite B Q, the whole weight would remain hung in the Centre B, even as in the ſite B A the whole preſſes to the ſaid Centre. Whence it comes to paſs, that in this manner a weight is more or leſs heavy, by how much 'tis hung Farther from or nearer to the Centre; and this is the only Cauſe whereby one and the ſame weight in one, and the ſame mean becomes heavier or lighter. And although I call the ſide B C *Horizontal*, ſuppoſing it to make a right angle with C O, whence the angle C B Q becomes leſs than a right angle, by the quantity of an angle equal to that which is made by C O and B Q in the Centre of the Elementary region, yet this hinders nothing ſince the ſaid angle is but of inſenſible Magnitude: From the ſame reaſons we may conclude, that if the point u be equally in the middle between the Centre B and the extream C; the weight F or M will hang or incline according to the half of the ſaid Centre B: And if the ſaid u be nearer to B than to the point C, it will hang from it or incline to it more than the half; and if more towards C, it will be leſs than half.

PROPOS. VII.

How to know what quantity any weight or moving power hath in respect to another quantity, by Perpendiculars *drawn from the Centre of the Ballance or beam to the line of Inclination.*

Fig. 17. FRom what has bin said 'tis easy to understand, that the quantity B u which is almost perpendicular from the centre B in the 16 *Fig.* to the line of Inclination F *u*, is that which hath led us into the knowledge of the quantity of the force of F in this site or position, to wit, the line F u making with the arm F B an acute angle B F *u*: Nevertheless for the better understanding whereof we will imagin in *Fig.* 17. the beam *b o a* fixt in the Centre *o* at whose ends or extreams there is fixt or hung two weights, or two moving powers or forces *e* and *c*, yet so that the line of inclination *e* that is *b e* make a right angle with *o b* in the point b; and the line of inclination *c* that is *a c* makes an acute angle or an obtuse with *o a* in the point *a*. Imagin then the line *o t* perpendicular to the line of inclination *c a*, whence *o t* will be less than *o a* by the 18 Prop of 1 *El. of Euclid*: Moreover imagine *o a* to be cut in the point *i*, so that *o i* be equal to *o t*, and in the point *i* hang a weight equal to *c*, whose inclination make it a line parallel to the line of Inclination of the weight *e*, supposing nevertheless the weight or power *c* to be greater than *e*, in such proportion as *b o* is greater than *o t*; without doubt by the 6th. *Prop.* of the 1st. Book of *Archimedes de equiponderantibus*, *b o i* will not be moved from its site, but if in stead of *o i* we imagine *o t* made one with *o b*, and the power attracted by the line *t c*: *e* in like manner also will touch as *b o t* according to common reason the site is not moved; therefore that which was proposed is done, also, hence we may easily note, how much vigor and force of weight or power *c* at a right angle with *o a* loses, drawing less: Hence also follows this Corolary, that by how much nearer the centre *o* of the ballance is to the centre

centre of the elementary region, by ſo much alſo it will be lighter.

PROPOS. VIII.

From the two laſt Propoſitions all the cauſes of Ballances and Leavers depend. Fig. 18.

THe force of any arm of a ballance or Leaver that is long, is greater than a ſhorter, from the Preceeding propoſitions, that is, a weight placed on the end of the greater or longer arm, preſſes or endeavours more as it hangs more or leſs from the Centre.

Wherefore *Ballances* or *Leavers* are not purely *Mathematick* lines, but natural, and hence bodies exiſt conjoined with matter; now lets imagin *n s* to be a ſuperficies which according to length cuts the Axis of a *Ballance*; and we will ſuppoſe its Centre firſt in *i*, and the greater arm to be *i u*, and the leſſer *i n*, and the *Vertical* line *i o*, which let be ſo much as is the thickneſs of the *Ballance* from the upper to the lower ſide; for the better underſtanding whereof ſuppoſe *n s* a *Parallelogram*, and put two equal weights on the ends of the arms, experience teaches that the weight at *u s*, is of more force than the weight at *n x*, and we would know the cauſe of this effect.

We have already ſaid that *Ballances* or *Leavers* are of matter, and *n s* the medium of its ſuperficies, ſuppoſe now *i* to be the Centre, which ſtaies the ſaid *Ballance* or *Leaver*; let *u s* and *n x* be the lines of inclination of the weights, and we will imagin that the ſaid weights hang from the points *u* and *n*, as indeed they do, although they ſhould hang from *s* and *x*, becauſe the point *u* and the point *n* are ſo conjoined with *s* and *x*, that he that draws one, draws the other alſo: Likewiſe we'el imagin the two lines *i u*, *i n*, and *i e* which *i e* makes the angle *o i e* equal to the angle *o i n*; Hence it appears clearly if we hangthe weight *u* (which is equal to the weight *n*) at *e*, that hath plainly the ſame force as the weight *n* hath, and the *Beam* or *Ballance* will neither move up nor down, becauſe both

both weights equally lean to the centre *i*, by the middle lines *e i* and *n i*, but the ſaid weight being placed in *u*, the line *u i* by which the weight preſſes to the Centre, is more *Horizontal* than *e i*, and the line of inclination *u s* is more diſtant from the Centre *i* than the line *e t*; whence the weight in this manner being alſo more free from the Centre *i*, reſults and is more ponderous than when it was in *e*, for the reaſons mentioned in the two precedent propoſitions, and for this cauſe weighs up the weight placed in *n*. But if the Centre were in *o* and we imagin two lines *o s* and *o x*, and ſuppoſe the weights placed in *s* and *x*, whence the line *o s* will be more *Horizontal* than the line *o x*, and the line of inclination *u s* will be more diſtant from the centre *o* than the line *e t*, its weight will alſo be heavier, becauſe it hangs ſo much farther from the Centre *o*, and by reaſoning as aforeſaid we find the ſame effect to be true: In *Ballances* rightly and properly ſo called *x i s* or *n o u* may be *Horizontal*, but in all kinds of *Leavers* this only is ſaid by a certain ſimilitude; we may contemplate the ſame by ſuppoſing the Centre in the midle between *o* and *i*, which any one may eaſily do of himſelf without any other help.

Mechanick

Mechanick-Powers.

OR, THE

Definitions of the *Leaver*.

BOOK II.

1. A *Leaver* is commonly a piece of a *Fir-pole*, or other Timber, about 6 feet in length, which we use either to raise or move heavy bodies, such as Timber or Stone, or any body of metal, or such like; wherein three points are assigned, first the power of the movent 2ly; Of the weight to be moved; 3ly, The prop, to which the *Leaver* is annext, as to a Centre, describing two arches with a double motion.

2. Hence because these 3 points may be disposed three ways in this length, they produce 3 kinds of *Leavers*. First a *Leaver* of the first kind is that wherein the prop possesses the middle place, and the power and the weight possess the two ends, or extreams of the *Leaver*, as if the Power be in A, the *Prop* in B, and the weight in C.

Fig. 19. A *Leaver* of the second kind is that wherein the weight is placed in the midle, and the power and the *Prop* at the ends.

A *Leaver* of the third kind, hath the power placed in the midle and the weight and the *Prop* at the two ends.

Before I enter on the Propositions, I shall premise some things worthy our animadversion.

Fig. 20. Suppose the *Leaver* to be *o s*, *u*, *x*, whose *Prop* (or *Hypomoclion*) is in the point *o*, and the weight in the point *n*, 'tis clear that when you would raise it, it behoves also by the help of the hands to raise *u*; now we must consider how the weight *n* endeavours towards *u*, and for this cause we will imagin the right lines *n o*, *n i*, *n e*, *n t*, and *n u*, of which *n i*, is placed towards the Centre of the world, and *n t* makes an angle *i n t* equal to the angle *i n o*: Now placing some power in *i* having equal inclination to the upper, as *n* has to the lower (setting aside the gravity of the *Leaver*) this power (according to common reason) will sustain the whole weight of the said *n*, and if the weight *n* were in *x* directly over *o*, the whole weight would be upon the *Prop*, and so much force or power of the *Prop* will suffice to resist for sustaining, as is the gravity of the weight; but putting it again in *n* 'tis clear that if another power be not opposed from the neither to the upper part of the *Leaver*, the *Prop* notwithstanding being excepted, it will behove the power of some part of the weight *n* (without consideration as aforesaid of the weight of the *Leaver's* matter or substance) that the *Leaver* be depressed from the part, *s*, *u*, and some one part of the weight *n*, because other part of the same weight endeavours it self to the *Prop o*, by means of the line *o n* which makes not right angles with *o x*. But if from the point *t* this kind of resistance oppose it self that the *Leaver* be not depressed or born down,'tis clear by common sence that the power of the weight *n* is divided equally in the middle, whose moiety over *o* resteth,as also the other over *t* being in the middle of the two lines *n o* and *n t*. Now imagin the resistance *t* to be taken away and placed in *e*, it is clear also that the greater part of the weight *n* forces or endeavours to *e* by help of the line *n e*,more than to *o*; since the line of inclination, *n i*, is nearer to *e* than *o*: Because all resistance either in *i* or in *e*, or in *t* or in *u* is instead of a centre as well as *o*, and the work of one helps tother; But if the same resistance be placed in *u*, 'tis clear also that a lesser part of the weight *n*, endeavours to *u* than to *o*; since the said *n i* is farther distant from the centre *u*, than from the Centre *o*, and the proportion of the part of the weight *n* in *o*, to the proportion, of the part of the weight *n* in *u* will not be according to the proportion of the angles *u n i* and *o n i*, but according to the proportion of *u i* to *i o*, which may clearly be comprehended by the converse of this effect,

effect, that is even, as now we have supposed *o* and *u* to be two Centres that sustain the weight *e* of *n*; also imagin *n* to be a certain Centre from whence hang two weights *o* and *u*, so proportioned to each other, that *u i* and *i o* are the certain causes of the ballance of these weights *o s*, which we call a *Leaver* or *Beam* inclined on no part: But returning to the proposition, we say, That the weight of *n* endeavoring less to *u* than to *o*, that is to *t*, there needs less force in *u* than in *t* to raise the weight *n*; and so by consequence, the farther the point *u* is from *t*, the lesser force is required, and consequently when the force or resistance in *u* is so proportioned to that which is in *o*, as is *o i* to *i u* the *Leaver* or *Beam* will not be moved: But when there is a greater proportion of the resistance of *u* to that which is of *o*, than of that of *o i* to *i u*, then the part *u s* of the *Leaver* or *Beam* will be elevated: But if the proportion be lesser than *o i*, to *i u*, than the *Beam* or *Leaver* will be depressed on the same part.

Of Augmenting Force or Power.

Fig. 21. IN some places Bakers use a certain instrument for kneading their Past, which is perform'd by one man only, which instrument seems worth our taking notice of, and 'tis thus: Imagine the plain in which he sets who kneads the Past, and in which the Past is laid to be T S D, and the triangle T A S fixed, and perpendicular to the superficies of the said plain; and in the Angle A joyn a piece of Wood or Leaver A E as a moveable semidiameter and equal to the Perpendicular of the Triangle, whence A will be the place of the centre, and D O will be the semidiameter which kneads the Past, and from its end O (which O when D O is Horizontal is found in the base of the said Triangle) comes the piece of wood O V, which with A V is equal to the perpendicular imagined from the angle A of the base T S playing too and fro in O and V, that the semidiameter D O may be raised and depressed. And V O is equal to A V, and V is in the middle between A and E, whence A V with O V are equal to A E; moreover there are two pieces of wood perpendicular from

A, and fixt to the base and immovable; and so far distant from one another, that between them O V and D O may pass above and beneath, and not depart from the semidiameter D O. In the end of E there must be a small piece of Wood at right Angles with A E, which is held by the hands of some body which stands on the foresaid Machine, which man with that wood that is, the semidiametre A E drawing it to himself from the superficies of the said Triangle, and then thrusting it towards the same Triangle, he excites the semidiameter D O upon the Past with a great force.

In imitation whereof I have subcribed Fig. 22. *b a u x*, in which we may imagine *u* resembles A in the 21 Fig. and *a* denotes O, and *o* V, and *x* E: we may also imagine *u a* to be the base of the Triangle *a u o*, to which *o t* the perpendicular of the said base add *u a*; hitherto then *u o* will be equal to *o x*, and to *o a*, we may imagine also *a o* so produced to *b*, that *o b* be equal to *o a*. Also suppose a weight in *a*, to force towards *u*, whence the line of its inclination will be always *a u*; suppose also *a o b* to be a Beam or Leaver, and *o* its Centre, whence the force or power of *a* will be proportional to *o t*, with respect to the force or power imagined in *b*, the inclination of the perpendicular *b a*, which force or power in *b* will be proportionable to *b o* by *Prop.* 7. of this Treatise; therefore if you should place a certain power in *b* at a right Angle drawing the line *b o* so proportionated to the power of the perpendicular *a*, as *o t* is proportioned to *o b*, the Beam *b o a* will not be moved, but any greater portion in *b* will overcome *a*: And when *o x* is equal to *o b*, the same will happen according to common Sense, placing the power *b* in *x*. The quantity therefore of the power in *x*, which ought to overcome the resistance in *a*, which is put against *u*, ought to have a little greater proportion to resist, which in *a* makes a right Angle with *a o*, than that which is of *o t* to *o x*.

Prop.

PROPOS. I. Fig. 19.

A Theorem.

I*F in a Leaver, the Power be to the weight as the distance of each from the Prop, reciprocally, it will be in* equilibrio, *or the power will sustain the weight, but not raise it.*

Suppose the power A to the weight C, to be as the distance BC to the distance AB; I say, it will be in *equilibrio*, and the power will sustain the weight C, but not overcome nor raise it; but to the better understanding of the Proposition, suppose the weight C to be 100 pounds, and the power A to be a power able to sustain 25 pounds without a leaver; and as the power A is equivalent precisely to a fourth part of the weight, so also the line BC must be a fourth part of the line AB to make it in *equilibrio*.

The Demonstration. The power is increased in the same proportion in which its motion is increased above the motion of the weight; but in such disposition the motion of the power is to the motion of the weight, as 4 to 1; for if the leaver be understood to be raised in L, so that the power describes the arch AL, the weight describes the arch KC; but the arches are a like, because the angles ABL, CBK are equal; or like arches opposite to the *vertex*, are as their Semidiameters, to wit, as AB to BC, and we suppose AB to be 4 times as much as BC; therefore in such disposition (by the first principle of this Treatise) the power A is quadruplicated, and therefore is equivalent to 100, but a power of 100 is in *equilibrio* with a weight of 100; therefore if as the power A to the weight C, so the distance CB to the distance AB, which is reciprocal, it will be in *equilibrio*, which was to be demonstrated.

PROPOS. II.

A Theorem.

If the proportion of the Power to the weight be greater, than o the distance of the weight to the distance of the Power from th Prop, the power will raise the weight and overcome it.

Fig. 19. Let the proportion of the power A to the weigh C be greater than of the distance BC to the distance AB I say, The power A so disposed will overcome the weigh C.

Demonstration. Suppose another power which hath the sam proportion to the weight C, as the distance BC hath to th distance AB, this power will be in *equilibro* with the weigh (by the precedent proposition) but the power A is greater tha that power (by the 10th proposition of 5 *Euclid*) therefore th power A is greater than that which is in *equilibro* with th weight C, therefore it will overcome the weight C, and wi raise it; which was to be demonstrated.

PROPOS. III.

A Theorem.

Fig. 23. *If the proportion of the distance of the Power from th Prop, to the distance of the weight from the Prop b greater than of the weight to the power, the weight will be overcom and raised by the Power.*

Suppose a greater proportion of AB to BC than of th weight C to the power A, I say the power will overcome th weight C.

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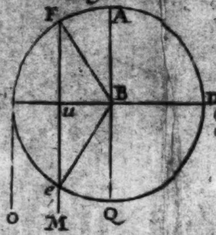

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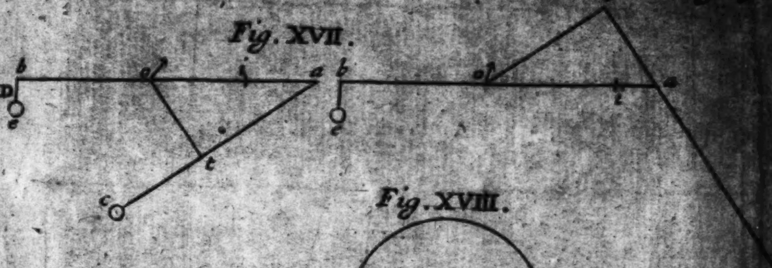
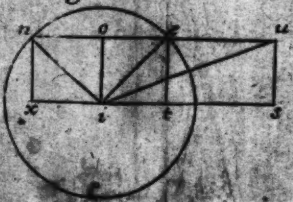


Fig. XVIII.



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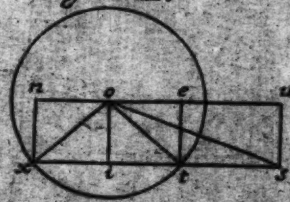


Fig. XIX.

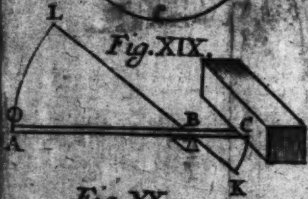
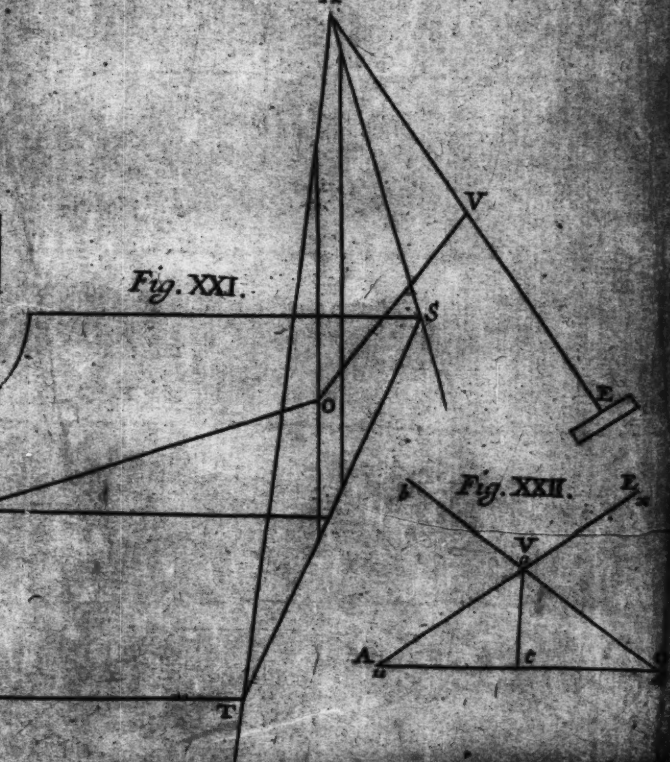


Fig. XX.

Fig. XXI.



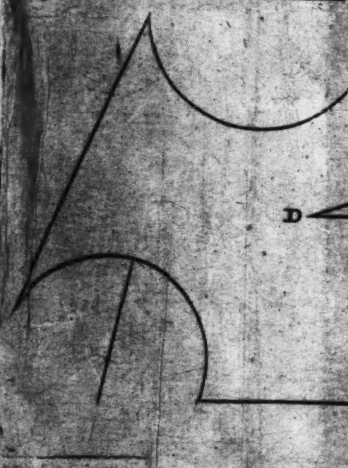


Fig. XXII.

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The Demonstration. Suppose another power D equal to A applied in the point D, so that as the weight C to the power D, so DB to BC (it will be by the 10th proposition of 5 *Euclid.*) DB less than AB, and (by the first of this) the power D applied in the point D will be in *equilibro* with the weight C: But the power A equal to D if it be applied in the point A, hath greater motion with respect to the motion of the weight C; therefore by the first principle hath greater force than the power D which is in *equilibro* with the weight C, wherefore that will overcome and raise it; which was to be demonstrated.

PROPOS. IV.

A Theorem. *Fig. 23.*

If the proportion of the weight to the Power be greater than the distance of the power to the distance of the weight, or if the proportion of the distance of the weight to the distance of the Power be greater than of the power to the weight, the power will neither elevate nor sustain the weight.

First, Let the proportion of the weight C to the power A be greater than of the distance AB to BC; I say the power A is to little to make an *equilibro* with the weight C; For suppose the power E to which the weight C hath the same proportion as AB to BC, and consequently the proportion of the weight C to the power E will be less than of the same weight C to the power A, and (by the 10th of 5 *Euclid.*) the power E is greater than the power A, but (by the first of this) the power E applied in the point A is in *equilibro* with the weight C, therefore the power A is too little to be in *equilibrio* with the weight C; therefore can neither raise nor sustain it.

Secondly, Suppose the proportion of the distance BC to the distance AB to be greater than of the power A to the weight C; I say, The victory will be in the power of the weight C, for suppose the power E to be as BC to AB, so E to C, and the proportion of the power E to the weight C, will be greater than of the power A to the same weight C, and (by the 40th of

5 *Euclid.*)

5 *Euclid.*) the power of E will be greater than of A; but (by the first of this) the power E applied in the point A is in *equilibrio* with the weight C; therefore the power A is less than that which is applied in the same point of the Leaver, in *equilibrio* with the weight C, therefore the power A cannot sustain the weight C; which was to be demonstrated

Although in the Figure I have only put a leaver of the first kind, these proportions agree equally with the 3 kinds of Leavers, since in each kind as well the powers as the weights describe Circles.

PROPOS. V.

A Theorem.

A *Power is equivalent to so many powers equal to it self in force, as its distance from the Prop contains the distance of the weight from the same.*

Fig. 24. Suppose any power A fit to sustain without a Leaver, a weight of 100 pounds, so disposed in the Leaver that the distance of A from the Prop contains four times the distance BC of the weight from the same Prop or Centre; I say the same power in the point A is equivalent to 4 powers equal to it self in force, and so can sustain in this disposition of the Machine or Engin, a weight of 400 pounds.

The Demonstration. As many times as the distance AB contains the distance BC, so many times the motion of the power contains the motion of the weight, but (by the first principle of Machines) how much the motion of the power increases above the motion of the weight, it hath so much the more strength or force, therefore according to the proportion of AB to BC, the force of the power will be increast; but by supposition AB is fourtimes as much as BC, therefore the power applied in the point A is equivalent to 4 powers equal to it self in vertue or force.

Or the power A equal to 100 pounds, will be equivalent to 4 powers equal to it self in vertue, if it sustains 400 pounds; and it can sustain them (by the first of this) if it be as the power

power A to the weight of 400 pounds, ſo the diſtance BC to the diſtance A B, which plainly appears.

PROPOS. VI.

The Power being placed the ſame diſtance from the Prop, and the weight being placed nearer to the Prop encreaſes the force of the Power.

Fig. 24. FIRST let the weight C be diſtance from the Prop B the diſtance of BC, and let the power be in A; I ſay if the power be always in the point A, and the weight be removed from the Prop B, ſuppoſe to the point E, that by how much the leſſer B E is, by ſo much the greater will the force of the power be, in order to ſuſtain or raiſe the weight placed in E; That is if the power applied in the point A can ſuſtain or ſupport a weight of 400 pounds placed in the point C; I ſay, If the weight C be removed from the Prop and placed in the point E; It will be as BE to BC ſo the weight of 400 pounds to that which the power A can ſuſtain.

The Demonſtration. For let it be as BE to BD ſo the weight C to the weight F; I ſay the weight F placed in the point E will be in equilibrio with the power A, for when 'tis as the power A to the weight C, ſo the diſtance BC to the diſtance AB; as alſo BE to BC, ſo the weight C to the weight F; Therefore from diſorder'd equality (by 23 of 5 Euclid) the power A will be to the weight F as the diſtance BE to the diſtance AB, then (by the firſt of this) A and F will be in *equilibrio* which was to be demonſtrated.

Corollary. I.

Fig. 25. From this Propoſition arrives ſeveral practiſes which naturally or experimentally Workmen make uſe of for moving of weights, or overcoming the reſiſtance of any bodies; And neither is this Doctrine only uſeful in raiſing and removing of heavy bodies, but alſo in cutting off bodies and parting them from each other, and overcoming any reſiſtance, which I ſhall only ſhew in brief, that it may be turned from them to other matters.

Firſt in digging Stones out of Qarries, they often uſe a Leaver or Croe of Iron, and when the Stone reſiſts much, either by reaſon

reaſon of its greatneſs, or becauſe it will not eaſily be ſeperated from the other to which it adhears, they remove the Prop as near to the weight as may be, that ſo they may move it the eaſier, and for the Prop they commonly make uſe of a Stone; or ſometimes two Stones, as if the Stone E F were to be parted from the Stone D E, if D E be firm, the Prop will be in the point C, and the weight in B, and it will be a Leaver of the ſecond kind and then the diſtance of the power will be the line A C, the diſtance of the weight will be B C; then as many times as B C is in A C, ſo many powers equal to it ſelf will the power placed in the point A be equivalent to.

But if the weight B be ſo drawn back from the body C E which the proportion of the Prop hath, that the diſtance C B be made greater, there may be put between thoſe two bodies, ſome hard body, that ſo the diſtance C B may be leſſened, and the force of the power more and more increaſed.

Fig. 26. In like manner when a Nail is to be drawn with a Hammer, by how much the Nail (which obtains the force of a weight) is nearer the Prop C, the eaſier it is drawn forth; whence when the Nail is drawn out a little way, ſo that the end of the Hammer C cannot reſt on the Board or Timber that the Nail is in, we are wont to put another body between, that the diſtance may be leſs.

Fig. 27. In like manner in Pinchers is a double Leaver of the firſt kind, one whereof is the Prop, to wit, the Nail or Rivet B, about which each part is turned, and by how much leſſer the diſtance B D is, and the diſtance A B or B C the greater, ſo much the more it ſtrains.

Fig. 28. The ſame may be ſaid of Shears, wherein this may be noted, The more they are opened the eaſier they operate; becauſe that when they are more opened the body to be cut, is nearer the Prop B; *Example*, Suppoſe it in D, but when they are ſhut farther, that which is to be cut, ſuppoſe it to be in the point E; whence the proportion of the diſtance of the weight from the Prop is greater than the diſtance of the power from the ſame Prop or Centre; moreover the longer the Arms A B, C B are, the more the force of the power is encreaſt, and thus we ſee Workmens long Shears cuts any kind of Mettal; many other Inſtruments we might mention, which this principle eaſily diſcovers.

When

When we open a Lock with a Key, if it opens hard, we put a Stick into the ring of the Key and turn the Key with it, for by so doing we make use of a longer Leaver, than when we turn the Key with our hand upon it.

When we open Gates or Doors, if we lay hold of them further from the Hinges, they open easier than when we lay hold on them nearer to the hinges.

Also from this we may give a reason why a long Staff or Pike weighs more if it be lifted up by one end, than if nearer the middle; as also why a long Stick, or Staff; or piece of Timber, is bowed or broke with more ease than a shorter.

Hence likewise a reason may be rendred, Why in Mills some teeth are made stronger and nearer together than others, *viz.* the foremest; many things we may run through which may be reduced to the Leaver; as in Navigation, the governing or Steering a Vessel, rowing with Oars, *&c.*

PROPOS. VII.

A Problem.

To move any weight with any Power *by a Leaver of the first and second kind.*

Fig. 29. LET there be given any weight B, and a power A, how little soever; I say the weight B may be moved by the power A, with a Leaver of the first or second kind; for since the weight B is not infinite, it will have some proportion to the power, therefore divide the Leaver C D, and make it, as the weight B to the power A: So the line C E to the line E D; suppose the Prop in the point E, and the weight applied in the point D, and the power A in the point C; I say it will be in *equilibrio.*

The Demonstration. For since the power A is to the weight B, as the distance E D, to wit, of the weight from the Prop, to the distance C E; to wit, of the power from the Prop (by

the first of this) it will be in *equilibrio*, but if the Prop be moved never so little to the weight, the power will overcome the weight and raise it.

We will do the same by a Leaver of the second kind, for make it, as B to A, so F H the length of the whole Leaver to GH, and let the Prop be at the end as at H, the power at the other end at F, and the weight in the point G, as yet (by the first of this) it will be in *equilibro*; but if the weight be moved never so little to the Prop, the power will raise the weight, and overcome it.

But a Leaver of the third kind, we cannot use to effect the same thing, for when the weight is placed at one end, and the Prop at the other, the power which possesses the middle place will always be less distant from the Prop, than the weight will; and is so far from helping the Machine to encrease the force of the power, that it hinders it, and the weight from such disposition of the Machine increases its resistance; for generally speaking, as often as the disposition of the Machine increases the force of the power; so often, if the power and the weight change places, the force of the power is abated, and so much the resistance of the weight encreased.

And this is *Archimedes*'s great Problem, That he would move the whole Globe of the Earth, if he could find but a place to fix a Prop upon, which in Speculation is true, but in practice impossible; for who can practically divide the length of a Leaver into any proportion, especially, if for Example, The Hundredth Thousand part of a Line were required, for it would make the distance of the weight so small from the Prop, that the seat of the Prop would be impossible to be distinguisht from the distance of the weight.

PROPOS.

PROPOS. VIII.

A Problem.

To place a weight so on a Leaver, that no finite power, how great soever, can overcome it.

Fig. 30. LET the weight A be never so little, and any power B equivalent to it, I say these may be so placed, that the power B, whatever it be, will be unable to raise the said weight. For suppose, as the power B to the weight A, so the distance K L to the distance L M, and the power B in the point K, and the weight A placed in M by (the first of this) it will be in *equilibro*; whence if the Prop L be removed never so little to the power consisting in K, it will be unable to raise the weight; also a Leaver given supposing the Prop thus, we may divide it, that a power being placed at one end, shall not raise the other end of the Leaver; *viz.* If we divide the Leaver KM, supposing the Prop L very nigh the power in the point K, it will come to pass that the power, though very heavy, will not raise the other part of the Leaver L M.

PROPOS. IX.

A Theorem.

Fig. 31. *WHen the Centre of gravity of a weight is in the line of the Leaver, the same force is always required to move it, whatsoever site it obtains, so that the force move only downward or upward.*

Those things which we have demonstrated concerning the Leaver, in the former Propositions are more universal; nor do they shew divers Circumstances worthy of Note, which here we ought to examine; And certain it is that a living power which is often used with a Leaver, since 'tis indifferent to all motion, it will move as well downard as a thwart. But weights which by their own nature gravitate only, resist motion upwards, and therefore their cicular motion is not so much to be considered, as their simple Perpendicular motion, which, that I may handle every one severally, I shall expose several Cases. And First, we shall take notice of the power forcing only downwards as it were, and so a weight may be compared in divers manners with a Leaver, for either the Centre of gravity of the weight, or as it were its middle is in the Leaver, and which is the same, is hanged freely on the Leaver, or it is above the Leaver, or beneath the Leaver: In this proportion we appoint the Centre of gravity in the Leaver.

Suppose the Centre of gravity of the weight A in the Leaver; I say, If the power only force downwards, the same power is required to sustain the weight in what site so ever it is.

The Demonstration. As well the weight as the power tend downwards, wherefore if the cicular motion be considered, both of the power and the weight, they will be proportionally distant, or their distances will be proportional, since like arches are proportional to the Semidiameters of their Circles; or if the perpendicular motions G E, C H be considered, they also will be proportional, because the Triangles C B H, B G E are proportionals; whence if the power move only downwards, the same force is required to sustain or move the weight, whether the Leaver be *Horizontal* or *oblique.*

PRO-

PROPOS. X.

Fig. 32. *A Power moving equally in every different place, moveth a weight more easily, whose Centre is in an oblique beam or leaver, than in an* Horizontal *one.*

Let the power be A, equally able to move a weight in any difference of place, and let the weight be D, whose Centre is in the Leaver; I say, If the Leaver be raised in E, the power will more easily move the same weight, than if the Leaver were *Horizontal*, as A D.

The Demonstration. Weight, or any heavy body, resists only motion upwards, therefore a Perpendicular line is its measure of resistance; Therefore, First let the weight be moved according to the Arch DE, the resistance will be the line EH, Secondly, let it be moved according to the other Arch equal to EF, the resistance will be according to the Perpendicular FI; And it is clear, that the line FI is less than the line EH: Therefore although the same power move through the Arch CB, equal to AB, and so advances the same vertue or force (according to the first principal) you will find less resistance in E than in D, therefore it will move easier while the Leaver obtains an *oblique* site or position, than when it hath an *Horizontal*; which was to be demonstrated.

Corollary.

Hence it follows, That in an *oblique* site a power is in *equilibro* with a weight, although the proportion of the power to the weight be not reciprocally the same, which the distance of the weight is to the distance of the power from the Prop; to wit, because the motion of the weight, according to which its resistance endeavours, is not the Arch EF but the Perpendicular line FI, although the motion of the power, according to which it exercises its activity should be by the Arch BC, but the Arch BC and the Perpendicular FI are not proportional to the distances KB, KE.

Nevertheless

Neverthelefs in an *Horizontal* fite DA, becaufe the Perpendicular Phifically falls in with the Circle DH, the common Rules ought to be obferved.

PROPOS. XI.

A Theorem.

Fig. 33. *IF the Centre of a weight be above the Leaver, the weight is eafier raifed above the* Horizontal *line than beneath, from the power only forcing downwards.*

Suppofe the weight A, and its Centre above the Leaver; fince the weight always preffes downwards according to a Perpendicular line; in an elevated fite it weighs downwards according to the line IF; and then the true diftance will be the line FE; but in an *Horizontal* fite the true diftance will be BE: In a depreffed fite it will be DE; 'Tis certain, that DE is greater than BE, and this greater than FE, and fo in refpect of the power applied in the Leaver, and only preffing downwards, the motion in C will be more difficult than in A, and in A than in I.

But what I have faid is with refpect to the power, its moving fimply downwards; becaufe if it fhould move equally, or alike in every different place, the proportion of the Doctrine delivered in the 10th Prop. would enfue.

PROPOS. XII.

A Theorem.

Fig. 34. *WHen a weight hath its Centre of gravity beneath the Leaver in a depreffed fite or Pofition, lefs force is required than in an* Horizontal, *and greater in an elevated fite.*

Suppofing

Suppoſing the Proof of the former Propoſition, this appears clear enough, neither doth it need any further explication, ſince in a depreſſed ſite the Perpendicular cuts off a leſſer or ſhorter diſtance than in the *Horizontal*, and in an elevated ſite it cuts off a greater; the ſame caution is to be noted.

But when the weight freely depends on the Leaver, it is almoſt in the ſame manner, as if the Centre of gravity of the weight were found in the Leaver: For always the ſame diſtance remains to the Prop or Centre, eſpecially vertually, becauſe the weight ſo moved, is as if it truly exiſted in that point of the Leaver whereby 'tis hung.

PROPOS. XIII.

A Theorem.

Fig. 35. *If by reaſon of the Figure of the Prop, the point on which the Leaver reſts be changed, the proportion alſo of the force of the Power, to the reſiſtance of the weight will be changed.*

The Figure of the Prop. may be various, and it may be ſo made, that in its motion it may bear the force of one or another point of the Leaver; whence it comes to paſs, that the diſtance of both the power and the weight are not the ſame; and ſo the whole proportion of the force of the power to the reſiſtance of the weight is changed; as if the Prop. ſhould be Sphærical, and the Leaver in an *Horizontal* ſite ſhould touch it in the point A, but in an elevated ſite it would touch it in the point B; The ſame I ſay if the Prop. ſhould be an oblong.

PROPOS.

PROPOS. XIV.

The motion of a power oblique to the Leaver, is less powerful than when right.

Fig. 36. IF the power be A, which presses the Leaver according to the oblique line A B; I say this motion is less powerful or able, than if the same force prest the leaver according to the perpendicular line A C.

The Demonstration. That motion tends not so much in raising the weight, as in drawing back the leaver from the Prop, as the motion A D forces the leaver against the Prop, and consequently it rather resists the Prop. than the weight.

PROPOS. XV.

A Theorem.

A motion so pressing forward to the weight, that it forces it obliquely to the line, according to which it should be moved, is less powerful.

Fig. 37. THE weight is A, which should only move according to the line A B, and the Leaver whose Prop is in C, touching the weight in the point D, and forcing it according to the line D E; I say, The motion of such weight will be more difficult than if it had been forced according to the line A B; for the force of motion according to the line D E, as composed of a double motion, to wit, as it were of a Perpendicular, and of an *Horizontal*; I say; as often as 'tis Perpendicular, it resists the subjected plane, and so part of that force is used in vain, in overcoming this resistance.

Prop.

PROPOS. XVI.

A Theorem.

When two Powers consisting at the ends of a Leaver, sustain a weight hung on it, that which is neerest to the weight sustains the greater part of the weight, and that which is further, the lesser part proportionally to the distances reciprocally.

Fig. 38. There are two powers A and B consisting at the ends of the Leaver, and sustaining the same weight C; I say, the Power A sustains a greater part of the weight than B; that is, if the weight C be 60 pounds and B C the double of A C; I say, the power A sustains 40 pounds, of the weight, and the power B sustains only 20 pounds: Or that the powers may sustain the weight C, the power in B must be equal to a weight of 20 pounds, and the Power in A equal to 40 pounds.

The Demonstration. The Power A in respect of the Power B is as the Prop, therefore that they may be in *equilibro*, it ought to be as, A C, the distance of the weight from the Prop A, to A B the distance of the power from the same Prop, so the power B to the weight C reciprocally (by the first of this) but A C is by supposition a third part of the line A B, therefore there is required in B a power equal to a third part of the weight, to wit, of 20 pounds; In like manner, because with respect to the power A, as the power B hath by means of the Prop, so will be the distance C B of the weight from the Prop, to A B the distance of the power from the same, as the power A to the weight C reciprocally, (by the first of this) but C B is supposed to contain two third parts of the whole line A B, therefore also the Power A will be equal to $\frac{2}{3}$ parts of the weight C, to wit, of forty pounds: Which was to be demonstrated.

Corollary. I.

If the weight be precisely in the middle, each power sustains only an half part.

Corollary. II.

Both Powers taken together, ought to be equal to that power which can raise the weight without a Leaver.

Corollary. III.

Hence we may determine whether the Prop be fit to sustain the weight, for it always agrees with some part of the weight, especially in Leavers of the second kind.

Corollary. IV.

In a Leaver of the first kind, the Prop sustains as much of the weight as the power, and its resistance ought to be equal to both taken together.

Corollary. V.

When 2 powers consist at the ends of a Leaver sustaining a weight placed in the middle, we may easily determine how much of that weight each power bears, to wit, by dividing the whole weight according to the proportion, which the powers have with the weight reciprocally; What I have said in respect of the Leavers bearing or sustaining the weight, may also be understood of drawing a weight; As if 2 draw, and the weight A be fixt, not in the midle of the Leaver BC; the Leaver will be moveable only about the point D.

PROPOS.

PROPOS. XVII.

A Theorem.

Powers consisting at the ends of a Leaver, do not bear the weight easier on a longer Leaver than on a shorter.

Fig. 39. Let the powers be A and B, and the Leaver likewise A B, sustaining the weight C; and let there be 2 other powers D and E sustaining the same weight, or one equal to it, on the longer Leaver; I say the length of the Leaver D E adds nothing to the facility; for let there be the same proportion of A C to C B, as of D F to F E, I will shew in both cases that the same part of the weight is sustained by the power B, as is sustained by the power E, and the same by the power A as by the power D: In like manner (from *Corollary* 2) I will shew in both cases that the powers taken together are equal to the weight, whence the greater Leaver effects no more than the lesser.

Neither doth it seem strange, that the length of the Leaver adds nothing to the force, that is, if two Leavers of unequal length, but divided alike from the Prop, that is, let the proportion of the distance in both be a like, the like effect follows in both.

PROPOS. XVIII.

A Theorem.

While 2 Powers sustain a weight, whose Centre is above the Leaver, in a declined site, the lower Power bears the greater weight.

Fig. 40. Let the 2 Powers be A and B, and let the weight be above the Leaver and its centre C, and let the perpendi-

cular be C D: I ſay, the power B ſuſtains greater part of th weight than if the Leaver were in an Horizontal ſite; For th weight always acts by a line perpendicular to the Horizon, a in this caſe by the line G E, when before it acted by C D, there fore the weight becomes nearer the power B: wherefore th power B bears a greater part of the weight (by the prece dent.)

But if the weight be beneath the Leaver, the contrary hap pens, as in the ſecond example, in which the weight hang on the Leaver by the line I K, which weight inclines to th power F, and therefore in this caſe, the power F bears mor weight, than if the Leaver were in an *Horizontal* ſite; Laſtly if the weight hang freely it will not change the ſite. and con ſequently, neither power ſuffers by the declination of the *Lea ver* or *Beam*.

PROPOS. XIX.

A Theorem.

WHen a power draws by a line oblique to the Leaver, its tr diſtance is a perpendicular from the Prop, to the line of D rection.

Fig. 41. Let the Leaver or Beam be A B, and the powe drawing by the line B C oblique to the Beam, to which fro the Prop F is drawn a perpendicular F D; I ſay, the true diſ ance of the power to be look'd upon, according as the increa or decreaſe of the vertue, or force, is the line F D.

The Demonſtration. Suppoſe the power to conſiſt in the poi D, which draws the cord from D in E, and draw the li F E; In the mean time the Leaver deſcends in the point draw the line E G, and becauſe in the triangles F D B, F E the ſides F G, F B, alſo F D, F E, and the length of the Chor B D, G E is the ſame (by the 8th of the 1ſt. of *Euclid.*) all t angles will be equal, among which G F D, B F E will be equ and the common angle B F D being taken away, there remai the angles G F E, D F B equal, and conſequently the arches B

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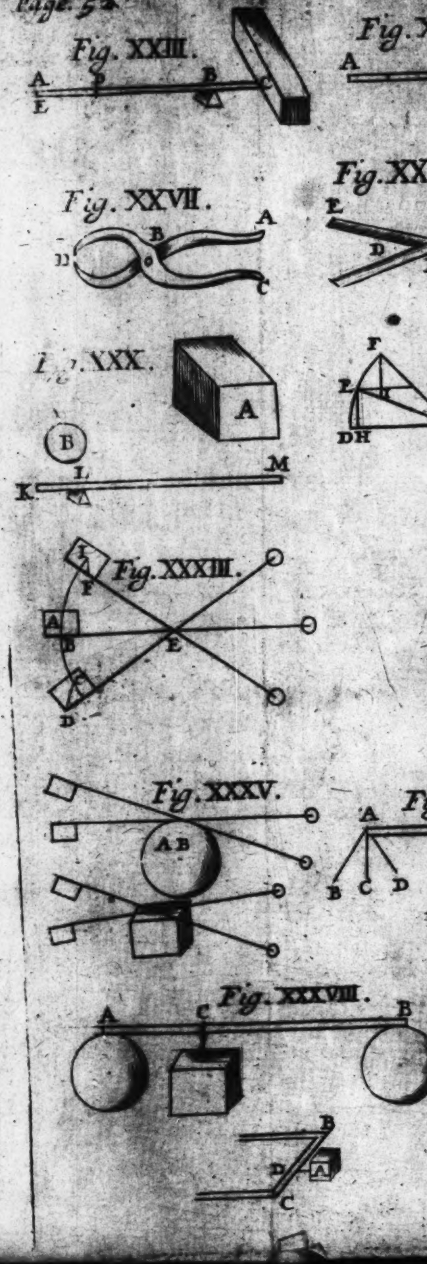


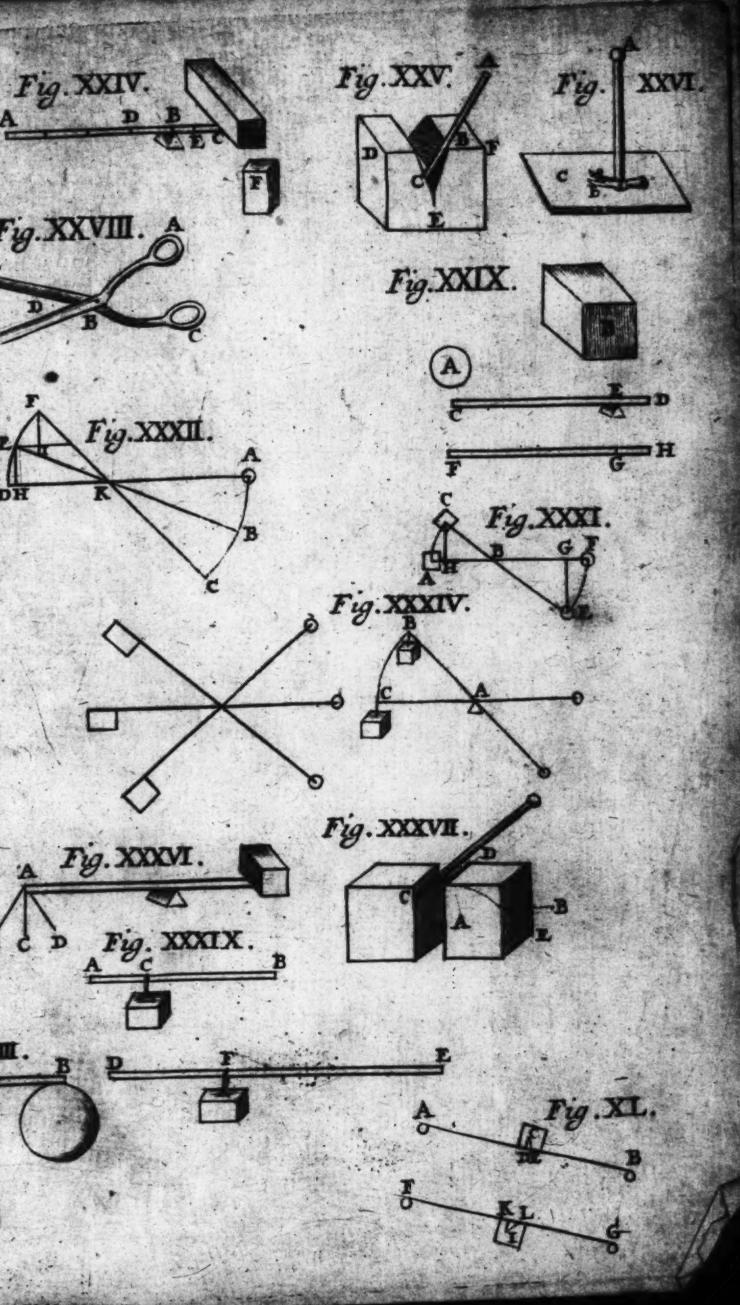


Fig. XXIV.
Fig. XXV.
Fig. XXVI.
Fig. XXVIII.
Fig. XXIX.
Fig. XXXII.
Fig. XXXI.
Fig. XXXIV.
Fig. XXXVII.
Fig. XXXVI.
Fig. XXXIX.
Fig. XL.

HI equal. But the arch DE according to which the power is moved, is to HI or BG, or AK the motion of the weight, as FD to AF: therefore the true distance, according to which the motion of the power encreases or decreases in is the line FD, perpendicular to the line of direction; which was to be demonstrated.

But if the power be in the point C, and it move upon the Circumference MC, it may easily be shewn that the arch MC, is equal to the arch BG, and consequently in this case the true distance seems according to that which is lookt upon as its force, to be the line FG or FC, which would be contrary to the precedent part of the proposition: But the line BC is supposed to be flexible in the point G, and so the power placed in C may move about the point B, as about a Centre, although the Leaver FG remain unmoved. Supposing then from the point B, as from a Centre, we describe the arch CO, so that the line BO, which may be imagined, be equal to the line BC; draw a chord from the point O even to M, so that in the mean while the end of the Beam pass from the point B, to the point G, and OM will be the true motion of the power, which I affirm to be equal to the line DE; For since DC or DO is one half part of the line CK, and EM half of the line MG; then DO and EM will be equal, and that which is common being taken away, *viz.* EO, then DE and MO will be equal, wherefore the power in on that end of the line is not more moved than if it were applied in the point D, therefore its true distance will be FD; which was to be demonstrated.

Corollary. I.

If the line BC be not Flexible, neither in the point B nor any other, but firmly adheres to the point B, the thing will be otherwise; for if you apply the power in the point D, its distance according to what is examined of the increase or decrease of the force, will be DF, but if it be applied in the point C, its true distance will be the line FC, and its true motion, according to which it moves, will not be only the line MO, but the whole arch MC.

Corollary

Corollary. II.

Fig. 42. The line of direction which is perpendicular to the Leaver is most apt to move, and by it the power hath the greatest force that it can have at the end of the Leaver; for let the Leaver be A B, the Prop C, and let the line of direction B D be perpendicular to the Leaver A B: I say, in any other line of direction, the power is less able; for let it be another line B E, which makes an accute angle C B E, and which consequently falls within the circle, draw to it the perpendicular C F, which (by the present) is the true distance of the power, and less than C B, wherefore when the Leaver draws by the line B E, it hath less force than by the line B D. Moreover let there be another line of direction B G, and the angle C B G obtuse, and consequently the other angle C B H will be accute, and B H will be within the circle which being divided in the middle in I, (by 3 of 3 of *Euclid.*) C I will be perpendicular to B H, and the same C I will be the true distance of the power; which since 'tis less than C B, the power also will have less force.

Corollary. III.

Fig. 43. The true distance of weights which draw by gravity only, is a Segment of the Leaver *Horizontally* placed between the Prop and the perpendicular; let the Leaver be A B, the weight by its gravity drawing downwards in B: Suppose the line E F in an *Horizontal* site, and draw the perpendicular B C; I say, the true distance of the weight B is D C, for all heavy things draws by a vertical line to which the *Horizontal* line D C is perpendicular; I say, the same if the weight were in the point H, the true distance would be D G. Whence it follows, that a weight depending on a Leaver *Horizontally* disposed hath greater force.

And here I will add something out of the Learned *Casatus* his *Mechanics*; says he It may perchance be pertinent to our present purpose, and not unpleasant to the Reader, if I here declare something of an invention: When I heard a certain man, declairing that a Bell of a vast weight, was carried easily on Brass Wheels, which by length of time were worn out, but

by

by what artifice, or in what order they were diſpoſed, or made, he could not tell; Wherefore he conſidering with me how it might be done, I happened on this thought, that I eſteemed the moſt heavy bell, might eaſily be repulſed, by diminiſhing, or leſſening the reſiſtance, which ariſes from the wearing of the Prop, or Stay, and Axis together; For let B and C be two ſmall wheels (*Fig.* 44.) of ſolid Braſs, whoſe diameters are in ſome different proportion to the diameter of the axis on which the bell bears, or lies; And let the ſemidiameter of the Axis be A E, and of the little Wheels B E, in proportion double, therefore alſo the peripheries will be in the ſame proportion, therefore while the point I in H compleats a quadrant, the little Wheel alſo is turned about, whoſe periphery is equal to half a quadrant; Wherefore if to the little Wheel there ſhould be fixt an Axis, whoſe Semidiameter B G is equal to the Semidiameter A E, the rubbing or wearing will be made with $\frac{1}{8}$ part of the Periphery of the Axis of the little wheel B; but becauſe alſo in the little wheel C, the rubbing or wearing, will be made equal with the ſame Axis, almoſt nothing of moment is gained, becauſe the whole wearing is equal, as if the quadrant E O were turned about in a firm and hollow Prop: And it will rather be a leſſening of labour in carrying the bell, if the little Wheels were fixed to an Axis: and ſince the Axis is *Cylindrical*, the ſubjected Wheels doubtleſs will touch in a line, a ſmall part of the Prop; And the Axis of the Wheels ſuit or fit with their concave parts in the ſuperficies which are worn while the wheels are turn'd round: Unleſs by chance the *Convex* ſuperficies of the *Cylindrical* Axis B G, be ſomewhat leſſer than the concave ſuperficies of the Wheel; and therefore they touch each other according to a line as (by the 13th of the 3*d*. of *Euclid*.) 'tis eaſy to demonſtrate, which doth not often happen.

But 'tis not needful to make ſuch ſolid Axes to the Wheels B and C, For if the axis A E is convenient to bear the weight of the whole bell, a pair of equal Axes will reſiſt or bear double the weight: Therefore 'tis ſufficient if each of the Axes B and C, ſuſtain half the weight; But ſince the reſiſtance of the *Cylindars*, leaſt they be broken, ought to be in triple proportion of their diameters, 'tis ſufficient to find two mean continual proportionals betweeen the ſemidiameter A E and its half; for that which is next leſs to A E will be ſufficient, for the Semidiameter of a *Cylinder* having Subduple Solidity and reſiſtance,

ance, but ſtill the Semidiameter requires to be leſs, becauſe the weight bears or preſſes obliquely on the Axes of the Wheels B and C; whence the weight of the bell on thoſe axes is according to the lines A B, A C, and not according to the perpendicular A D: Therefore as A D to A B, ſo reciprocally the weight on A B to the weight on A D; but the weight on either axis is as the ſubduple (or half) Summ to the whole weight; therefore the weight on B A is leſs than ſubduple, and the proportion continuing is made leſs; For when the Semidiameters A E and B E are given, the whole B A is known; and B D, and alſo its equal B E is known; therefore (by the 47th. of 1ſt.of *Euclid.*) alſo A D will be known, whoſe quadrate you will find, if from the Square of B A you ſubtract the Square of B D.

Therefore if by *Hypotheſis*, B A, be 3, its Square is 9; and B D 2, its Square is 4, which ſubtracted from 9, there remains the quadrate 5, whoſe root is 2,23 and is the right line D A: The weight therefore on B A to the whole weight of the Bell on both axes B and C, is as 2, 23 to 6,00: But becauſe the reſiſtance of like ſolids is in triplicate proportion of their homologal ſides (and in *Cylinders* the proportion of their diameters is had) if you ſeek two mean proportional numbers between 6, 00 and 2, 23 which you may do if you draw the quadrate of one extream into the other extream, for the Cube root of the product is the term next to that number whoſe ſquare you aſſumed: Therefore firſt, the Square of 6, 00 being 36, 0000, draw it into 2, 23 and the cube root of the product 80280000 is 431, $\frac{1}{3}$: But the quadrate of the other extream 2, 23 is 49729 being drawn into 6, 00, gives 29837400 whoſe cube root 310, is the other mean; Therefore the 4 numbers 600,431$\frac{1}{3}$,310,223, are continual proportionals, the fractions being ſlighted; Wherefore if you make it as 600 to 431, ſo the ſemidiameter A E to B N; this ſemidiameter ſought will be ſufficient to bear the weight.

And becauſe B E is the double of A E, and A E to B N is made as 600 to 431, B E will be to B N, as 1200 to 431; And according to this ſame proportion will the Semiquadrants be that are deſcribed by them. But the eighth part of the *Periphery* from the radius B E, is equal to the quadrant from the radius A E; therefore the quadrant E O to the Semiquadrant of the radius *B* N, is alſo as 1200, to 431, Therefore if the rubing upon of the axis of the bell with the fixed Prop and hole, be 1200,

the

the Wheel B with its Axis is 431, to which the rubing upon of the other Wheel C with its Axis is equal; and therefore the under Wheels the diameter whereof is only double to the diameter of the axis of the bell, the rubing upon is as 862 to the rubing upon which is as 1200; If therefore the diameter of the Wheels to the Axis of the bell be not only double, but triple or quadruple, the rubing upon will be much lesser, and the facility in carrying the bell greater.

Mechanick-Powers.

OF, THE

Wheel or Axes in *Peritrochio.*

BOOK III.

Fig. 45, 46. AXes in *Peritrochio*, which in Latin they call *Suculum*, or *Windlace*; It consists of a *Cylinder*, or round piece A *B*, to which is fixt an Axis C D, it hath also handles or radius's fixt to the *Cylinder*; about the *Cylinder* a rope is turned to which the weight is fastned, sometimes the Axis C D, is parrallel to the Horizon, as in *Fig.* 46, and sometimes it is perpendicular to the Horizon, as in *Fig.* 45. and may be variously made, and yet its essence; or being, remain unchangeable, and the same power persevering in augementing; For whether the handles be immediately fixt to the *Cylinder*, as in *Fig.* 46, or whether they be fixt to the Circumference of the Wheel, as in *Fig.* 45. it differs little, for the true length of the radius is the distance of its end from the Axes.

PROPOS. I.

A Theorem.

THe *Wheel or Axis in* Peritrochio, *is a Ballance or Leaver.*

Fig. 47. Let the baſe of the *Cylinder* be A *B*, its Centre, or the Common Section of the baſe and Axis the point C, which when 't is immovable hath the force of a fulciment or Prop, let the weight hang from the point A, and the Power in D, I ſay there will be found a *Ballance* or *Leaver* of the firſt kind, for although the handle *B* D be not always fixt in the ſame plain wherein the weight A is found, nevertheleſs it deſcribes an equal Circle to that which it runs over, if it exiſt in the ſame plain; and therefore is found to be a *Ballance* or *Leaver* of the firſt kind, And the ſame Propoſitions which we have made of the *Leaver* may be applied to this Engin, ſince the increaſe of the motion of a power above the motion of a weight is the ſame; Therefore (by the firſt principle of this) the increaſe of force is the ſame: But in the ſecond caſe in which the weight depends on the point F, the Prop is in H, and the Power in G, 'tis a *Leaver* of the ſecond kind.

But if the power be in the point K, the Prop in L, and the weight depend on the point M, as yet it will be found a *Leaver* of the firſt kind, but being thus diſpoſed, the force of the Power is diminiſhed.

Laſtly, If the *Fulciment* or *Prop* be in the point O, the Power in P, the weight in R, it will be found a *Leaver* of the third kind, wherein the force of the weight is increaſed, and the force of the Power leſſened; notwithſtanding, this diſpoſition is not unuſeful when the power exceeds the weight by a longer interval or ſpace.

Corollary.

Corollary. I.

If the Power be to the weight, as the Semidiameter of the *Cylinder* to the length of the handle, or radius, the power in ſuch diſpoſition will be in *Equilibrio* with the weight: And I ſuppoſe the Power to be applied in the extream or end of the radius, and to force the handle always perpendicular; The reaſon is clear, becauſe (by the firſt Principle of this) 'tis then in *Equilibrio*, when the Power is to the weight, as the motion of the weight to the motion of the Power reciprocally. But the motion of the weight is to the motion of the Power, as its diſtance from the Axis, to the diſtance of the power from the ſame Axis: For while the power abſolves one circle about the Axis, the rope alſo is once turned about the *Cylinder*, and the weight abſolves an equal motion to one circumvolution, or one circle of the *Cylinder*, but Circles are to each other as are their Radius's, Therefore if the Semidiameter of the *Cylinder* be to the length of the handle, as the power to the weight, it will be in *equilibrio*, and the power will ſuſtain the weight; which was to be demonſtrated.

But that the force of this *Engin* may be the better concieved, take the Semidiameter of the *Cylinder*, and compare it with the length of the handle, which take from the Axis to the point in which the power is applied; and as often as the Semidiameter of the *Cylinder* is found in the length of the handle, ſo often is the power multiplied; that is, let there be a man in *Equilibrio* with 100 pounds, and let the Semidiameter of the *Cylinder* be 10 times found in the handle; I ſay, the ſame man can with this *Engin* ſuſtain 1000 pounds.

Corollary. II.

But if there be a greater proportion of the power to the weight, than of the Semidiameter of the *Cylinder* to the length of the handle, the Power will raiſe the weight; for greater force is required to move a weight, and to overcome its reſiſtance, than to make it even, or level.

In like manner if there be greater proportion of the length of the handle to the Semidiameter of the *Cylinder*, than of the weight to the Power, the power will be superior to the weight and overcome its resistance.

Corollary. III.

If the power move the handle by a line, not perpendicular to the same; Its true distance from the Axes or Prop will be lesser: As if in *Fig.* 48. the handle be BC, and the power draws by the oblique line C E; the true distance of the power according to which we ought to measure its increase or augmentation will be the perpendicular B D (as is shewn at Proposition 19. of a *Ballance* or *Leaver.*)

Corollary. IV.

If a rope be so turned about a *Cylinder* that it makes the folding spiral, or that one Spiral folds on another, it makes the difficulty of drawing greater, or increases the force of the weight; for when the Semidiameter of the *Cylinder* is increased, it makes the proportion of the length of the handle, to the Semidiameter of the *Cylinder* less (by the 10th. of 5th. *Euclid.*) or, that I may speak more plainly, the Semidiameter of the *Cylinder*, is not so often found in the length of the handle; if it happen that the *Cylinder* be not long enough to hold all the Spires, but it shall be needful to put one Spire upon another, since those Spires so put upon one another, necessarily increases the Semidiameter of the *Cylinder*, the same weight will have unequal force, and will sooner move the Clock or Watch, whence it follows that the first hours are unequal and shorter; But if any one would have (for example) the third hour shorter than the rest, let him increase the *Cylinder* of the *Tympane* under the Spire which answers that hour and he will have his desire.

Corollary.

Corollary. V.

Fig. 49. From this propoſition you may underſtand wherefore in watches, which are not animated by weights, but by ſprings, wherefore I ſay the *Cylinder* about which the ſtring or chain winds is not made *Cylindrical* but Conical, as in this figure, for when the ſprings in the beginning, are more ſtretched than towards the end, therefore they have greater force than the reſt; In the beginning they ought to draw by the Apex of the Cone, that is, then there is but a ſmall diſtance from the Axis, but in the end they draw by the baſe of the Cone, in which part there is a greater diſtance from the ſame Axis; to wit, that greater force drawing from a leſſer diſtance, or in a ſmaller motion, may be equal to the force of a leſſer drawing from a greater diſtance: For let the force of the ſpring in the beginning of drawing, to wit, when 'tis moſt ſtretched be equal to one pound weight, and in the end equal to the weight of 4 ounces, or $\frac{1}{4}$ part of a pound; the Semidiameter of the Circle of the Cone in which the String or Chain is knit, in the beginning of drawing ought to be $\frac{1}{4}$ part of the Semidiameter of the Cones baſe, according to which the drawing is made in the end, for thus the force in each caſe will be equal and will draw uniformly.

Corollary. VI.

Fig. 50. Hence may eaſily be ſolved a queſtion oftentimes propoſed to me, to wit, whether the ſame weight hanging on a long cord hath more force than if it hung on a ſhort cord; or whether it be harder to draw the weight A than the weight B, which I ſuppoſe to be equal; The reaſon of the difficulty ſeems to be becauſe the weight A is farther diſtant from the Axis of the *Cylinder* than the weight B, and therefore ſeems to require more force; therefore we ſay not any diſtance from the Axis is the meaſure of the increaſe of force, but that only from whence follows greater motion; therefore whether the weight exiſt in A or in B, while the *Cylinder* is turned round once, the weight aſcends according to a line which is equal

to the Circumference of the *Cylinder*; therefore in each case the weight is equally moved, therefore equally gravitates; notwithstanding I exclude the weight of the rope, or cord.

But if these weights hang not freely, but the lines BD, AC should be of rigid matter and inflexible: Because while the *Cylinder* is turned about, the weight A describes a greater Circle than the weight B, the same weight A will have greater force than the weight B, according to the proportion of distances.

PROPOS. II.

A Theorem.

While a power acteth by the force of its own gravity, the increase of the Power doth not always ought to be required from the distance of the Axis.

Fig. 51. Although we have toucht upon this proposition already: Neverthelefs we will fit it peculiarly to this Engin, because that 'tis already known, and in common use with stone diggers; the Machine or Engin consists of a large wheel into which men enter, and in which they walk, also a *Cylinder* about which the rope is turned about, and an oblong neck, in whose extream or end is a Pulley to direct the weight; It may be questioned, whether the force of the power of the movent applied in the extream of the Wheel be increased, according to the proportion of the Semidiameter of the wheel to the Semidiameter of the *Cylinder*; to which I answer, it is not so, for when a man walks in a Wheel, and moves by gravity, to wit, by a line tending to the Centre of the Earth, applied in divers parts of the wheel, yea, often times almost under the Axis, Its true distance is not to be taken according to the Semidiameter, as if the man were walking in the point A, when he moves by the line A B, his true distance is C D; as is shewn in Proposition 19.

PROPS.

PROPOS. III.

A Thorem.

Of the windlace placed vertically.

Fig. 52. ALthough it matters not much how a *Windlace* is placed as to its site or position, yet a *Windlace* whose Axis is vertical hath this peculiar property, that it may be wrought by animals only, because that (properly speaking) animals only have their motion Horizontal, although also some mills are made in which water moves the *Windlace* vertically, yea, and the wind also, as we shall shew; I have often wondered that these kind of *Windlaces* are no oftner made use of in buildings, since by the help of a horse only, greater store of Stones, or Bricks, or Morter, may be conveighed to the upper-parts of the building, than by 4 or 5 men; Wherefore a vertical *Windlace* may be worked with a Mill-horse, and about the *Cylinder* a double rope may be turned about, in a contrary manner, so that in the mean while that one weight rises, it sends down the other Instrument. The force of this *Machine* will be very great, for when a horse can carry more than 300 weight, he will draw much more, or raise by drawing; we will suppose 500 weight, and his force increases according to the proportion of A C to A B; and for the most part A C contains 10 lines of A B, from whence it will be, that one horse alone may raise 5000 pound weight; but if the weights ought not to be so great, and it seem better to raise more small weights with respited force, than to take up a great weight together, and at once, lest the ropes be broke, then you may increase the *Cylinder* A B to any thickness that you please, for then you will lessen the force of the power, and sooner take up the weight.

Neverthelesss because in this *Machine* or *Engin* there seems this incommodity, that the weight being elevated, the *Windlace* ought to be turned the contrary way, and there would be

be ſome loſs of time, to turn the horſe the contrary way; firſt 'tis certain that if men were placed to this *Windlace*, that inconveniency would ceaſe: But if yet you would uſe a horſe, make a compounded *Machine* or *Engin* of two *Windlaces*, having two *Cylinders* with teeth, or toothed *Tympanes*, which vertical *Windlace* may move the other Horizontal, ſo that if the cogs or teeth of the *Cylinder* be put to the other, the *Cylinder* will be moved on one part; but if it incur in the other *Cylinder*, the *Cylinder* will be moved with a contrary motion; and 'tis eaſy ſometimes to move one, and ſometimes the other *Cylinder*, with a moveable Leaver about the cardinal point.

Fig. 53. This vertical *Windlace* is commonly uſed by ſeamen, chiefly in great ſhips, ſo that thereby they take great weights into ſhips, and draw out great anchors which require great force, both by reaſon of their weight, as alſo to dig them out and draw them from the earth, wherein they ſtick faſt; where in one thing is to be noted, that becauſe the Cables or great Ropes are oftentimes ſo thick, that if they are rolled about the *Cylinder*, and Spire is put upon Spire, they grow to a great mole, and render the Engin uſeleſs, therefore they turn only 3 Spires or 4 at moſt about the *Cylinder*, ſo that while a Seaman turns one end of the rope round it, the other is rolled away; And that it may always conſiſt in the middle, nor run through the whole *Cylinder*, the *Cylinder* is made broader at the ends after the manner of a Cone, as you may ſee in the Figure, for ſo the rope is kept in the middle.

Fig. 54. There are reduced to the vertical *Windlace* or Axis in *Peritrochio* your leſſer water-mills, in which the water diſpoſed in the wheel forces it ſo, that the Wheel is moved Horizontally, and its Axes vertically; We uſe this Engin when great ſtore of water is not at hand, and the greater the wheel is, the greater will the ſtrength of the water be, according to the proportion of the diameter of the Wheel to the diameter of the Mill; But in the ſame proportion decreaſes the velocity of motion in the Mill, for each turning round of the Wheel, anſwers each turning of the Mill, from whence it happens that great care muſt be taken that the Wheel be not made greater than is requiſite, for if it be there follows a ſlowneſs in the motion of the Mill, and the Engin is rendred leſs uſefull; likewiſe

if

if the Wheel be made less than the resistance of the Mill requires, there will be no motion.

To the same Engine are recalled other Wheels, which howsoever exposed to the wind, always turn round; for to what wind soever on one part, the Concavity of the little hand turns, the convexity of the other is also turned, as if the wind blew directly according to the line A B, the wind will touch the Concavity of the little hand A G B, and the Convexity of the little hand B A, but then it makes greater impression while it incurs in the Concavity, than while in the Convexity; because then it easily slips away, this Wheel is turned from A by G in B: And the impression of the wind may also easily be hindred in the little hands A, and then it will be turned more vehemently, to wit, if there be placed some obstacle.

This kind of Windlace is used, as often as we use Animals, but chiefly we use Mill-Horses when we work Engins, such as Mills, we grind all manner of Corn with, or Nuts, or Olives, or for the Extraction of Oyl; I omit several other Engins, which part of them are recall'd to this kind of windlace.

PROPOS. IV.

A Theorem.

Of the double Axis in Peritrochio, or a Wheel.

Fig. 55. THE most part of vulgar Engins are not so simple, but that oft times they contain a double Engin of the same kind; I shall not insist upon the Composition, which may be made from a double or triple ballance, or leaver; because for the most part such composure is useless, whence the first Composition which may be made for use is the double windlace, and sometimes a triple one, according as the thing requires: But because as we have said, the Windlace is recalled to a leaver, and that continually, therefore it will not be unprofitable briefly to note, how wonderfully a power is augmented by using a double Leaver; for let the leaver be A B, its Prop C, also let A C be to C B, as 10 to 1;

K Sure

Sure it is the Power applied in the point A, is equivalent to 10 Powers equal to it self, applied in the other leaver D F, so that E F be to D E as 10 to 1; the Power placed in F is equivalent to 10 Powers equal to it self, in respect of weight constituted in D: But if the leaver D F impells the leaver A B, the Power F will be equivalent to 100 powers equal to it self, in order to a weight constituted or placed in the point B.

And the reason is clear, the point F hath 10 times greater motion than the point D, but when the point D is conjoined with the point A, they make the same motion; but the point A runs through 10 times a greater space than the point B: Therefore (by the first principle of this) in such disposition of the Engin, the power constituted in the point F will be equivalent to 100, equal to it self, in respect of weight placed in the point B.

Fig. 56. Which Doctrine is applicable to Windlaces, if they are fitted in the same manner; as if the handle A C be 10 times greater than the Semidiameter of the Cylinder B, and the Rope annexed to the Cylinder B, moves the Windlace E, by the end of the handle D F, which also is 10 times as great as the Semidiameter of the Cylinder E: I say the power A is 100 times encreased with respect to the weight G, which is manifest.

Fig. 57. Notwithstanding, because in this disposition the Cylinder E absolves only half the turning about, therefore this Engin is rendred useless in many effects: Therefore if you would know the disposition in which the leaver D E may always draw, this will be, if the Rope be made (as they call it) perpetually turned round about the Cylinder A, encompassing the Wheel *B* C of the Cylinder D, and this Engin may be most useful, especially when the two Cylinders A and D are distant from each other a great space; nevertheless it hath this inconveniency, that oft times it happens that the Cylinder A is moved alone although the Rope draw not; and therefore they make the Cylinder A, rough with hollowings, and also they make knots or balls in the Rope which enter into the hollowings, and stay the Cylinder that it cannot move alone, as in the Figure E appears plainly.

Fig. 58. We use the same Engin, but in a contrary manner, when the power overcomes the resistance of the weight by a long space, but a most swift motion is demanded; as if the greater

greater Wheel be A about which the Rope is folded, and also about the lesser Wheel B, whose Diameter is contained 10 times in the greater Diameter: 'Tis certain that every circumvolution of the greater will answer 10 Circulations of the lesser; but in this disposition the power is lessened; that is, if the power as 1 be applied at the handle C, you may determine to raise some weight hung to the Cylinder D, there will be required a power 10 times greater to take it up, if it be hung on the Cylinder E. Howbeit this Engin is very useful, because oft times a power overcoming a resistance sustained by a great excess, cannot otherwise conveniently be applied: So they which sharpen Knives, and other edge Tools, on a Grindstone, have greater force than to overcome that resistance, whereby the Iron resists the motion of the Stone while it is held upon it, and requires a swift motion only, which cannot be produced from the power in like manner, because 'tis impossible to move the Arm so swift: In this case an Engin must be used, which encreases the motion, although it lessen the force of the power: This Engin is easie, and much used, and chiefly of Women which Spin; also when they draw out Silken Threads, or double them; also of those that pollish pretious Stones, of Turners, and of many others, and I wonder that 'tis not used by more.

PROPOS. V.

A Theorem.

Of Wheels with Cogs, or Teeth.

Fig. 59. TOothed Wheels are recalled to Axis in *Peritrochio*, and are easily understood by a perpetual leaver; wonderful is the increase of power in using such an Engin.

For since that while one Wheel is 10 times turned about, the other is but only once turned round, it causes each Wheel to increase in a decuple proportion, and therefore as shall

be demonstrated elsewhere, a number consisting of 50 Arethmetical Figures, is greater than the number of Sands which the whole Circuit of the Firmament can contain; but the number of each Figure added, increases in a decuple proportion, and from thence the power follows.

The Demonstration. Let there be a power in A which can draw to it self 100 pounds, and let C D be 10 times the Semidiameter E F, and let there be so many Teeth in the Wheel G, that E F may describe 10 orbs in the same time that the Wheel G describes one; Moreover let G be 10 times turned round while the Wheel L absolves one circumvolution, and so on; I say, the Power, as 100 placed in A, is able to elevate a weight of 100000 pounds.

For, since the power in A runs through a space 10 times greater than the little Wheel E F, and the little Wheel E F 10 times of the little Wheel M, and the little Wheel M 10 times more than N, and this again 10 times more than the Cylinder G H. The power A runs through 10000 times greater space than the weight P; but the power is increast according to the proportion whereby its motion exceeds the motion of the weight (by the first principle of this) therefore the power A in respect of the weight P, is equivalent to 10000 powers equal to it self: but A is supposed to be able to draw to it self 100 pound, therefore 'tis equivolent to 10000 powers which can each draw 100; but 10000 of such powers can draw 1000000; Therefore the power in A, by the help of this Engin can draw 1000000 pounds, which was to be demonstrated.

But on the contrary the weight loses as much of its force; whence if instead of the weight P, a power be placed which can elevate 100000 pounds, and the weight in the point A can only elevate a weight of one pound, but the loss which the power A suffers, is in time, for it ought, to make 1000 Circumvolutions in the same space of time that the Cylinder L absolves 1.

Also this Engin is inverted, or changed, as often as the force abounds in the power; and a most swift motion is required in the weight, which may easily be understood by the foresaid discourse, to wit, if the handle be in the Axis L, 'tis certain, that the Axis D E makes 1000 Circumvolutions in the same time that L or ly makes one.

K 2 Prop.

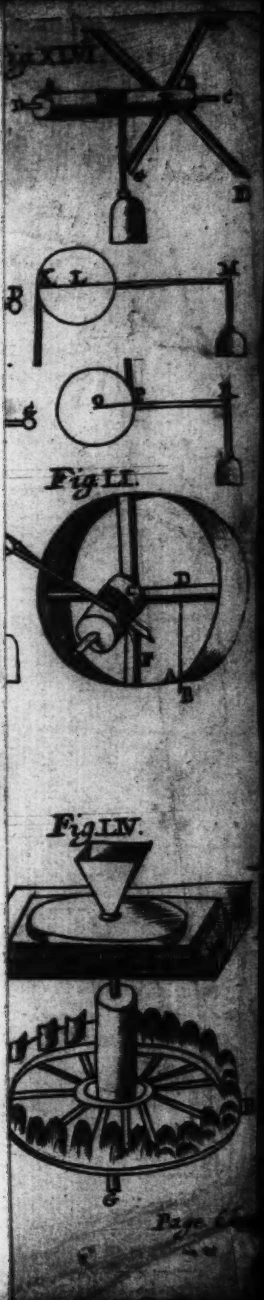


Fig. LI.
Fig. LIV.
D
C
F
B
G

Fig. XLI.

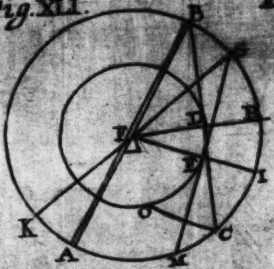


Fig. XLIV.

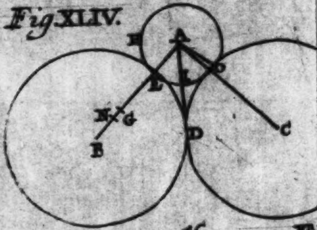


Fig. XLVII.

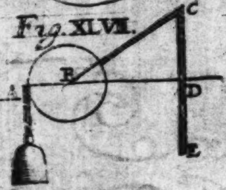


Fig. LI.

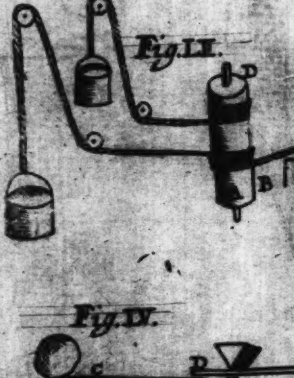


Fig. LV.

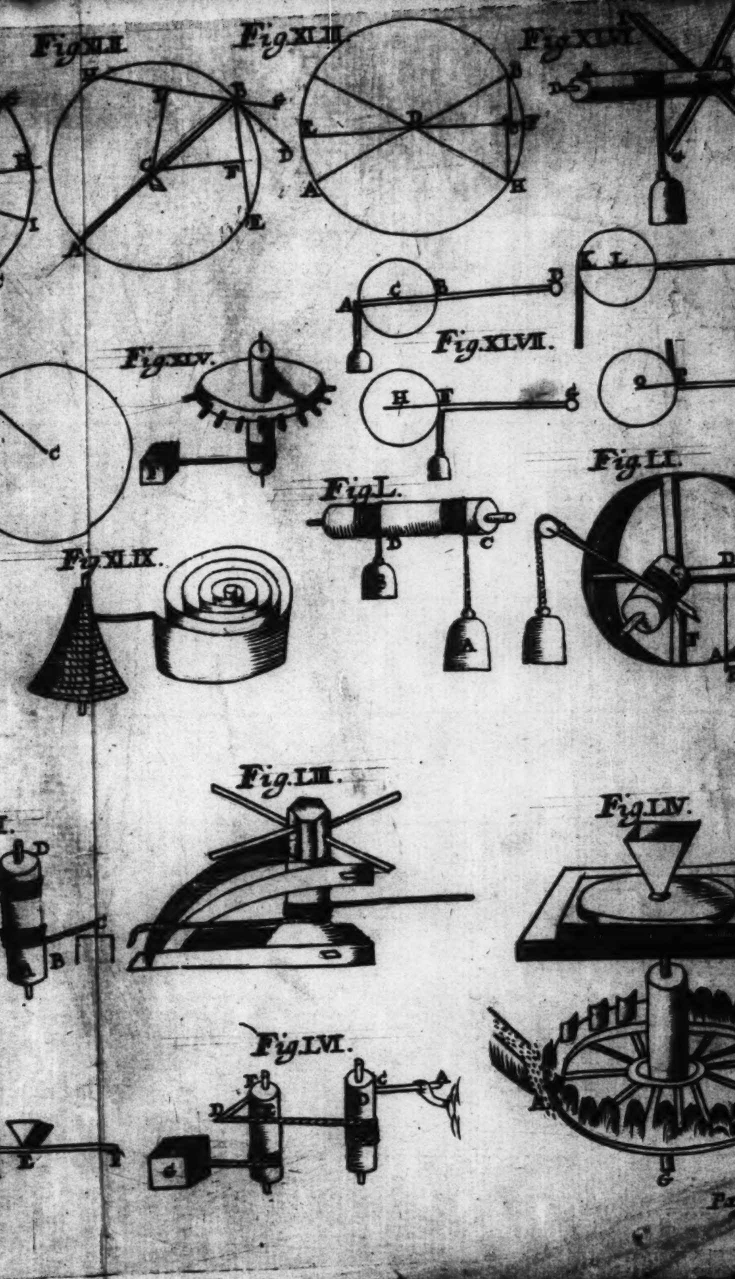


Fig. XLII.
Fig. XLIII.
Fig. XLVI.
Fig. XLV.
Fig. XLVII.
Fig. LI.
Fig. L.
Fig. XLIX.
Fig. LIII.
Fig. LIV.
Fig. LVI.

PROPOS. VI.

A Theorem.

To recall Toothed Wheels to the Leaver.

Fig. 60. THE whole multiplication of a power by help of Wheels, is easiy to recall to Leavers, yea he, that dilligently considers the nature of Wheels, may easily consider the perpetual leaver in them, for each Cog of the Wheel is a Leaver, which are substituted to themselves by turns, so that one being deficient another succeeds it.

And that we may consider the same in the Multiplication of leavers, let there be 3 leavers A B, D E, I H, and let A C be to C B as 1 to 10; in like manner D F to F E, and E I to I H: I say the power as 1 in H in respect of the weight A, is equivalent to 1000 powers equal to it self.

The Demonstration. H is 10 times more moved than E or F, and E 10 times more than D or B, and B 10 times more than A; Therefore the motion of the power in H is 1000 times more than the motion of the weight in A: but if there should be only one leaver K M it would be otherwise, for the leaver L M would be only 30 times the part K L, and so the power in M would be equivalent only to 30 powers equal to it self.

To this kind are recalled almost all Engins of any moment which we commonly use, and which in the following propositions I shall explicate, the Forces whereof if any one would consider, in general he must measure both the motion of the weight, and of the power, and compare them between themselves.

PROPOS.

PROPOS. VII.

A Theorem.

Of Engines moved by Water.

Fig. 61. AMong others those Engines are most useful, which are rather moved by Inanimate things than by Animals; because that Inanimate things want not nourishment, and are never tired or wearied; but Inanimate things which are wont to Animate Engines, are likewise all those things which cause Motion, as Water, Wind, Smoak, any kind of Weights, Springs, *&c.* In this Proposition I shall briefly handle those Engins of that kind which are moved by Water: And I find that Water can move an Engin in a double manner, either by an acquired force which can equalize a percussion, or simply by weight or gravity, thus some Wheels are made which bear Water on one part; in which 'tis requisite to know the precise proportion of the Axis in *Peritrochio*: So that the weight of the Water may have the exact proportion of the Power, and we ought to measure its force by the distance from the Axis, which in such case the forces of the handles bears: but when running Water moves an Engine or Machine not by force of weight, but by acquired force, that is done either because Water is conveyed by a plane much inclined, or running into wings, or little hands, but which method is best we will examine when we come to treat of *Hydraulic* Engines.

Fig. 62. But 'tis certain that greater Wheels have most force, for when in Windlaces the power is moved by a longer handle its force is increased, but likewise a requisite time is increast, whence I often find in common Mills unnecessary Expences laid out, to wit, they make the greater Wheels winged, in which the Water dashes, also because a slower motion should follow in the Mill, they add a greater toothed Wheel which runs into a lesser; so that while the greater makes one revolution, the Mill makes

makes 8 Circumvolutions; It is sufficient that the first wheel A B, equipt with little hands, be made less by one half, also the wheel C D to be ½ of that; so that E F shall make only 4 Circumvolutions in each rotation of the greater wheel A B; for the Water hath the same force in respect of the Mill E F, in moving by only 4 turnings about, and the Water will twice as soon turn the wheel A B, being lesser by half; and if we weigh or consider all these things exactly, and according to Mathematical Rules, the same thing would happen if the wheel A B should be eight times lesser, likewise C D should be 8 times lesser; so that each Circumvolution of the Toothed, or Cog wheel, should answer each Circumvolution of the Mill E F.

Which things, as I have said, are true, precisely speaking, notwithstanding we must consider one thing, *viz.* That greater wheels because they depart less from a right line, therefore their little hands are longer forced by the Water; but in lesser wheels each little hand is sooner elevated, whence in all these some mediocrity ought to be observed.

Fig. 63. Not only Mills for grinding of Corn, but also most other Engines, yea, almost all which are made in Water are reduced to this kind; First, all Mills for Corn, which are made on the banks of Rivers, or those that are made in little Ships, and in the middle of Rivers, or other Engins which are for grinding of Nuts, or of Bones to powder, *&c.* Also Engines to make Paper, in which a wooden Cylinder of sufficient magnitude standing out, furnisht with little troughs, takes up wooden Mallots, which bruise and break whatsoever is laid under them to powder; your Gun-powder Mills in like manner consisting in a Cylinder, equipt with like troughs, which take up Pestles of Mortars; for in all these we must consider Axis in *Peritrochio*, as well in the wheel which the Water forceth or driveth, as in the Cylinder and its troughs, taking up Mallots, or Pestles.

Fig. 64. Likewise Mills for Iron, in which also a Cylinder equipt with little hands, takes up and lets down an Iron Mallet of a sufficient greatness.

Fig. 65. And these are of divers kinds, according as they are diversly required to be made, for some are greater, and some are lesser, some pound oftner than others.

Fig. 66.

Fig. 66. Saws also which are drawn up and thrust down by the handle; also there is another part of the Saw which belongs to another kind, *viz.* to the Screw. Also Engines in which Bellows are wrought, or blowed, which belong to the same manner, as to motion upwards and downwards, but if four pair of Bellows are to be blowed together, the Axis ought to be made turning, or bowing, four opposite ways, that they may be moved in any order, and in each Quadrant.

PROPOS. VIII.

A Theorem.

Of Engines that work by the gravity of Weights.

ALso Engines are moved by Weights, and the force of their Gravity, as are our Clocks, notwithstanding I shall say in general, that all those Engines are not fit to augment the force of Powers, but to shorten time, to wit, that that may be done in a short time, which was wont to be done in a whole day; that is, let an index of hours be moved in a whole day, that it may shew the hours properly, if a man should undertake that without an Engine, he would spend the whole day; a weight being substituted by a man in one minute, in drawing or winding up the weight, uses as much force as is necessary to move the Hand or Needle the whole day.

The same I say, of Engines for the turning of Spits in convenient places, which have nothing peculiar but their motion of staying, or stopping, which we shall treat of hereafter; and these Engins are made after four manners, *viz.* with Weights, with Springs, by Smoak, and by some living Creature walking in a Wheel; of Weights and Springs I shall say nothing, for 'tis most certain I have found nothing in them more than toothed Wheels, and Axes in *Peritrochio*; and the Animals which are commonly made use of for the turning of Spits, are Dogs, but Geese are better, for they will bear their Labour longer, so that if there be need they will continue their Labour 12 Hours.

Prop-

PROPOS. IX.

A Theorem.

Engines moved by Smoak.

Fig. 67. ENgines which are turn'd by Smoak, ſhew plainly how much force. is increaſed by Axis in *Peritrochio*, for what force can there be leſs to impel and move a Weight than Smoak, nevertheleſs while this runs into the winged Wheel A B, all whoſe wings are bent in the ſame part, if the wheels are ſo fitted, that while C D makes four or five Circumvolutions, the wheel E makes one; and in like manner while the wheel E, or that annext to it F, is turned four or five times, the right line G is only once turned; A B makes 25 circulations in the ſame time that G, *viz.* the Spit makes one, I ſay, from this multiplication of motion in the power, to wit, in the Smoak, or in the wheel, into which the Smoak enters, the impulſive force of the Smoak is increaſed 25 times, with reſpect to the reſiſtance of the Spit placed in the point G, and I do not ſee any thing more in this Engine worth our taking notice of.

PROPOS. X.

A Theorem.

Of Engines working by the Wind.

Fig. 68. THe reaſon is the ſame of Mills turned by the Wind, in which alſo the ſails are bent in the ſame part, for they are not directly oppoſite to the wind, but every one in one and the ſame part are ſomewhat oblique,

almost in the same manner that Boys make paper Wheels on a Reed; so that while they run and hold it in the Air, 'tis easily turn'd, and because the force of the Wind and the violence is very strong, the Mill makes more turnings about than the winged wheel in a contrary manner, as in the precedent Engine. And the same question may be made of this kind of Wind-mill, which is made of common ones, to wit, whether they may not be more compendiously composed than commonly they are made; for since by the multiplication of the Wheels the motion of the Mill is increast, whether or no it would be better to make lesser wings, whence it will come to pass that the first Wheel will compleat its revolution sooner, and therefore there will not need so much multiplication of the Wheels, that the first Mill should obtain the same motion; 'tis also worth our consideration that the wind is not applied in one place only, but almost in the whole wing or sail, and therefore the greater the sail or wing is, the wind will not only have the greater force, because that it makes greater motion in the extream with respect to the motion of the mill, but also more plenty of wind is adhibited, whence I think 'tis better to use longer wings or sails than shorter.

The Art of Mills depends on Axis in Peritrochio.

TO reckon up all the Arts which depend on Axis in *Peritrochio* would be a thing not unpleasant, but almost an endless piece of work, and would be rather like a History than a Theorey, in which I chiefly write of the principal causes of Engines, shewing by what ingenuity every one may design or contrive Engins after his own manner meet for the purpose. And I shall insist a little on the making of Mills, that we may know how great profit we receive to the commodity of life from Axis in *Peritrochio*; and although those that are chiefly ordained, are Mills for grinding of Wheat, and other Seeds, that bread may be made of flower, yet some part of them are designed to other uses; for as much as the outer Wheel is common to all, which by water running into it, turns it and the Axis about. For if Wool, or Hemp, or Flax, be to be pounded, or any body ground to Powder, if old Rags are to

be

be beat to pieces to make Paper, little pegs or pins are fixt to the Axis, which in turning about meet with the pins of Pestles and raise them, and depress them, and their weight falling on the matter laid underneath, either batters or breaks it to pieces, or beats it to powder in Mortars.

In the same manner Pestles may be disposed to match with their hollow Cylinders, which being elevated by the little pins of the Axis, attract the water into the hollow Cylinders, or rushing in naturally they admit it through the Cells, then falling down by their gravity, they press the Water through the Tub, and force it to ascend to an higher place. Or if you like not Pestles so great and heavy, and would force Water to a higher place, dispose a pair of Pestles by a Rope, or Chain, put through the hollow of the upper Wheel, and passing over the Periphery joins them, or rather overthwart, like weights joined to a Beam, so that while one is deprest the other is raised. And the pin of the Axis depresses the Pestle, by whose force the water ascending in the Tub is prest, and the other Pestle being lifted up draws the Water placed beneath, which in like manner is prest down after that by the pin of the Axis answering its pinion; from hence it comes to pass that a longer Axis may be added to the Wheel, and more pairs of this kind of Pestles in like manner may be disposed, and the pins in the Periphery of the Axis so distributed, that not only more Pestles may press or force down together, but every one after another, if the power turning the wheel be not altogether so strong, if not, and it should be stronger, you may depress more together, and raise those that answer them; unless by chance it please more, to make use of two pair of Pestles in the same manner, with so many pins placed in the Axis, that in one going round of the same Axis, the same Pestle may be de[illegible] twice or thrice.

Moreover to this place appertains, what we see in many places in the Work-houses of Hammer-Smiths of Copper [illegible] Iron, where also the outer wheel being turn'd about, and the force of water failing, the inner wheel in the room turns as if it were turn'd by the hand, which radius of the upper Axis is fixt parallel to the Horizon, and a rule joined to it that may be folded in the Joints, while it lifts up and depresses that which is overthwart; on the other end of the same Axis, taking up in like manner from hence, and depressing from hence,

it procures an altern or changable motion to the Bellows; and the other wheel receiving a stronger force of Water falling down, and turning its Axis about, the pins fixt at the other end of the Axis depresses the little rafter or leaver, whose opposite end being raised, is joyned to a great Iron Hammer, which besides the fall of the Axis with pins of it self, lighting or falling upon the subjected copper or Iron being burnt in the fire, beats or hammers it.

In all these the Semidiameter of the Wheel is to be consider'd, in whose little branches standing out the water running into, retains the force of the moving power; but the Semidiameter of the Axis is not to be consider'd alone, but also the length of the pins that stick out to be added, so that from both is made one only Semidiameter of motion which is communicated to the pestle, or to the deprest end of the Hammer or Sledge. I say, to the depressed end of the Hammer, for the elevation of the Hammer is somewhat greater than its depression that a stronger blow may follow; for neither the little rafter or leaver is altogether equally divided from its Axis on which it stays upon, but the Hammer is a little farther from it, than the opposite end which is depressed, and therefore the depressing force is greater than if the leaver were distinguished into equal parts. Likewise in the motion of Bellows; first, the Semidiamer of the wheel is to be compared with the adjoining handle, moreover the radius fixt to the superior Axis, must be compared with half the piece that goes a cross to which the Bellows are joined, and from these two proportions is compounded a proportion of motion, or movement of the power, to the motion or movement of the weight moved.

But yet in Mills whose grinding stone for Corn is turned round parallel to an Horizontal plane, yea, and that very swiftly, that the grain may be dissolved into flower, 'tis not enough that the outer wheel receives force from the Water turning the Axis fixt to it, but also the lower toothed Wheel is required to be in the same Axis; and that the members, or parts, of the Engin be not multiplied in vain, they commonly so dispose the Mill-stones, that the Iron Axis that sustains the upper Mill-stone, being furnisht with a place to turn, or run in, obtains the lower place, and therefore the runner as near as may be touches lightly, the upper part of the neither toothed Wheel with its plane, having the same Axis with the outer Wheel.

But

But if the Mill-ſtones cannot be placed in a plane beneath, or above that which turns the lower toothed Wheel, but only a little beneath, or above, the Axis of the ſame Wheel; becauſe the chamfred turning joint joining very near to the Mill-ſtone, and ſo turning the Stone, is diſtant from the toothed Wheel, and this doth not ſo convenienly admit of ſuch long Teeth which the ſame turning joints, or the little rods of the runner, are able to mix with fitly; therefore there is required another Axis perpendicular to the Horizon with a runner, and a fixt Wheel, which ſhall turn about the lower Wheel of this Runner, forcing its little Rods with its Teeth; for the toothed Wheel parallel to the Horizon, being fixt to the ſame perpendicular Axis, is turn'd about together, and being joined with the runner of the Mill-ſtone turns it round.

Here alſo are many proportions compounded, the firſt is the proportion of the Diameter of the outer Wheel, to the Diameter of the inner Wheel in the ſame Axis; moreover the proportion of the Diameter of the Runner of the Mill-ſtone adhering to the Mill-ſtone turning round the Diameter (whether the whole Diameter be allowed, or only that part which is the Diameter of the Circle in the rotation of the Mill-ſtone deſcribed from the point between the Centre and the middle of the Periphery) and if, as in the ſecond caſe, the perpendicular Axis muſt be placed between; beſides in the Compoſition, comes the proprotion of the Diameter of the runner to the Diameter of the toothed Wheel, perpendicular in the ſame Axis; from whence it appears to be better, that the Diameter of the inner Wheel be leſs than the Diameter of the outer Wheel, that the force of the Water forcing this may be more ſtrong; but alſo we muſt take heed that we do not make it too little, ſo that its number of teeth ſcarce exceed the number of little Rods of the runner adhering to the Mill, for this will cauſe it to move too ſlowly; and if the perpendicular Axis be in the middle, ſuppoſing this equality of Teeth, and of the little Rods of the runner, one turning round of the outer Wheel will only once turn round the toothed Wheel parallel to the Horizon, and therefore in the ſame time the Mill will be only ſo many times turn'd about, as the number of little rods of its runner is contained in the number of Teeth of the toothed Wheel fixt in the perpendicular Axis.

But

But as you increase the number of times of the Mill's turning round, take heed that the difficulty of moving in like manner be not increast more than needs must; to wit, if the Diameter of the runner in the perpendicular Axis be excessively less than the Diameter of the Toothed wheel in the same Axis; if so be, a power applied in the runner will be moved much slower than a weight applied at the end of the wheel with Teeth, and therefore the difficulty of moving increased: Wherefore all things must be wisely administred, that neither the force of the moving power be tired in vain, nor the Mill be moved slower or swifter than need is.

But if it please not, or the disposition of the place permit not the middle Axis to stand perpendicular, but it happens more conveniently to be parallel to the *Horizon*, then the Teeth of the inner wheel having the same Axis with the outer wheel must not be fixt in the plane, but require to be fastned in the extream Periphery, that they may turn the runner of the superior Axis, (whether greater or lesser, according as is needful) and with it the wheel that is Toothed, not in the Periphery, but in the Plane, from which the runner of the Mill is turned.

Neither otherwise than before, is the proportion of force compounded, to wit, of the proportions of Tympanes or Water-mill wheels, or Crane wheels, which have a common Axis, as appears from what hath been said.

Hence we observe, because the moving power is Water, that the form of a wheel receiving Water is not to be always the same; for those wheels which are placed in a running Water would be inconvenient if they have a very large Diameter; or if but a little Water falling, the Impetus or force will be repelled, if the little hands be prepared to small. Therefore wheels of this kind should have indifferent Diameters, but the little hands possess a very considerable part of the Axis, being displaid very nigh the length of the Axis, that so by much Water running into them they turn round with a stronger force; so in the River *Poe* in *Italy*, commonly the length of this wheel is 15 Feet, the whole Diameter 9 Feet; the Diameter of the neither Stone is 8 Feet 3 Inches, having 108 Teeth fixed in the plane, and the runner of the Mill is distinguished into 9 Spindles; and the Stone of the Mill in thickness 6 or 7 Inches, and its Diameter 3 Feet 9 Inches: But

because

because the motion of Water falling from on high is greater than of a running Water, therefore the Diameters of the wheels ought to be larger if there be need, and it suffices if the breadth of the little hands be very indifferent, as being included in a Channel or Pipe, by which the Water falling decays, or is lost: That is to say, a little Water falling from a Plane more elevated, hath greater force than from a Plane almost *Horizontal*; and besides a wheel of a larger Diameter is easier turned although from less water, for it hath greater proportion to the inner wheel from the other pairs. Moreover the little hands commonly are plain, or but little bent, so that the water may run abroad here and there; nevertheless sometimes they are concluded on each part with a ledge, or welt, as it were a little Vessel containing water for sometime, so that the weight of the included water helps the turning, by pressing downwards; Moreover in an inclined channel, the force of the water is greater in the lower part than in the upper near the beginning of the fall; to wit, because water naturally descending hath an accelerated motion, and acquires an impetus from the descent of the antecedent.

Hitherto we have considered of Mills which are drove by the force of water, adding nothing concerning those which are turned by Men, or by living Creatures, for these have nothing peculiar, besides that the Axis of the first wheel which procures the motion of the rest of the consequent parts, is perpendicular to the *Horizon*, because a power moves easier in an *Horizontal* plane, than in a vertical wheel, or Tympane, which is trod or trampled on; and instead of the outer wheel driven by the water, a Bar is fixt to the Axis, which they either draw by Cattle, or work with Men.

Notwithstanding we will say somewhat of Mills which are wrought by the Wind, whether they be for grinding of Corn, or bruising of Fruit, or whether they be for working of Pumps, whereby waters are drawn from low grounds that are overflowed: For that which belongs to the inner artifice of wheels and runners, are like those which are found in our Mills moved by the force of water, unless that in those, that being remote from a level plane (if so be a fit place be granted, and the wind caught by a large van) they ascend by a pair of Stairs, and the Corn, or Fruit, is carried into the upper place which they intend to grind, bruise or break, and the

Flower

Flower is transferred from thence: which labour the Miller may be eased of, if by the same labour whereby the wind turns the prime Axis with its wheels; Sacks full of Wheat, or Flower, may be taken up, or let down, with a Rope drawn about the Axis, being lapt up, or unfolded: That which is chiefly to be considered in this kind of Mills, is that which pertains to the Vans, or Sails, which receive the wind, for even as the plane of the wheel is not directed according to the running of the water, so neither have the Sails such a dispofure that they follow the leading of the wind: But the upper part of the little House wherein the Axis with the Toothed wheel is contained, is turned about until the Vans, or Sails, are set against the blowing of the wind.

And the Vans or Sails are as it were 4 Ladders conjoined at right Angles in the end of the prime Axis, each whereof is covered over with Linen Cloath to resist the wind, which if it be pretty strong, the folded part of the Cloath will admit of some passage to the wind; notwithstanding these Vans or Sails, are not so equally placed, as to be in one and the same vertical plane, but the plane of each Sail is placed *oblique* to the other side, withdrawing it self by little and little from the wind; whence it makes the wind running between the intervals of the four Sails to repel on the sides, and as it were to smite the Sails by an Elbow, and so the Axis is turned according to the Inclination of the Sails; for if there were no *obliquity* of the Sails, and all as it were made one plane in which the Axis would be perpendicular, it would be uncertain in which part the turning would be; that which belongs to the breadth or length of these kind of Sails *obliquely* placed, 'tis not doubted but that the breadth of them helps the motion very much, because being placed in the same *obliquity*, a greater part of the Air runs into a larger than a narrower Cloth; and in a very strong Wind, least the velocity of the Engin be over much, we find sometimes that covering half the Sails with Cloth will do; but whether or no 'tis worth while to encrease the length of them, is uncertain: For although a power more distant from the centre of motion hath more force, notwithstanding, because the ends of long Sails are very much distant between themselves, the wind having obtain'd a larger space, hath less force; as also water flows swifter, and with a greater

endea-

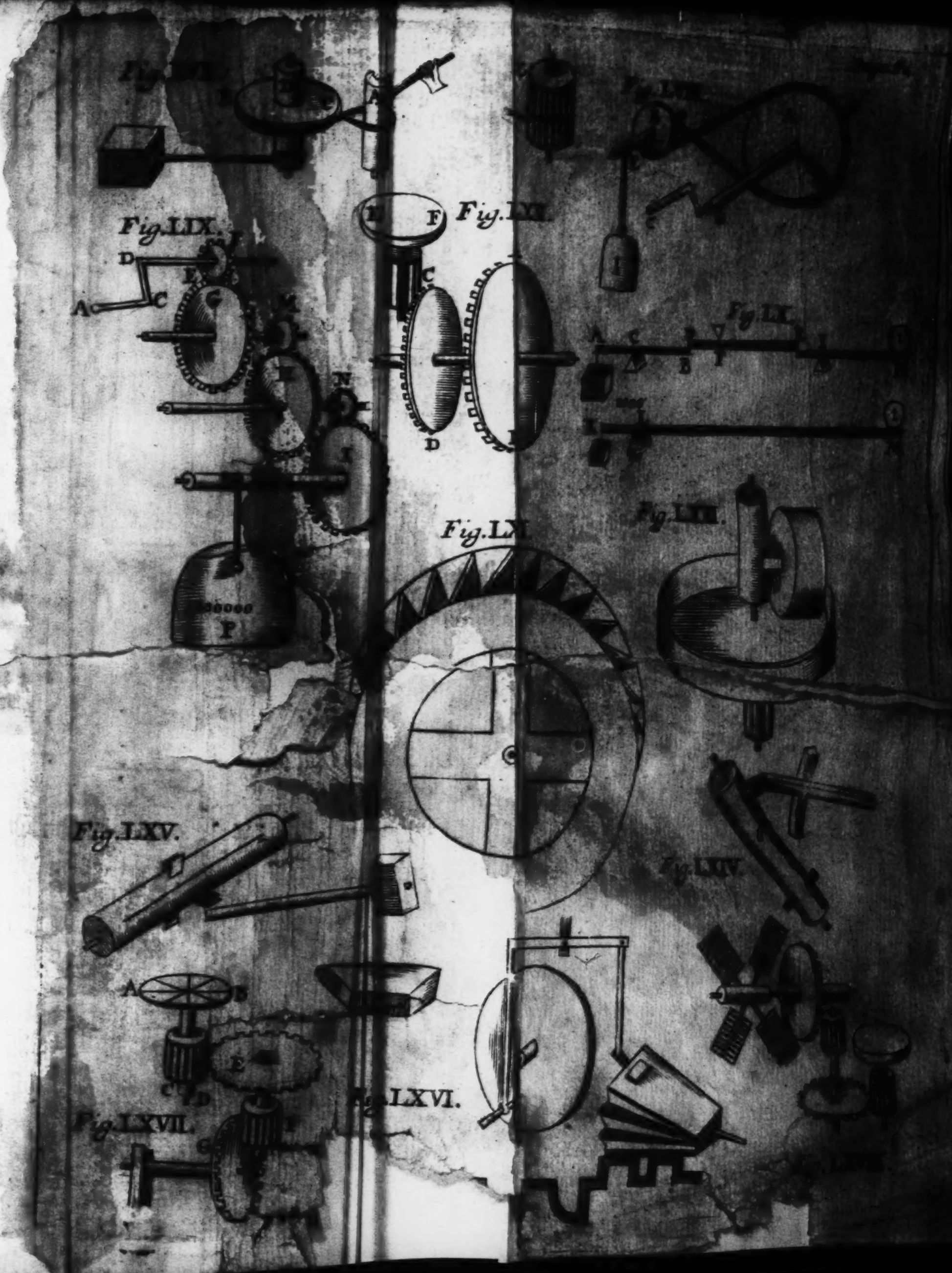
endeavour through a ſmall narrow place, than it runs through a wide open Channel; therefore I dare not intirely define in theſe kind of Sails, in what place the forces of the moving power ſhould be placed, as it were in the centre of vertue, or force; for near the Axis to which they are faſtned, the diſtance is ſmall, and the Wind as it were their object being ſtopped, blows more ſwiftly: And further from the Axis in a greater ſpace, it ſlides away more eaſily, and leſs incites the courſe of the Sails; but for as much as we muſt not raſhly appoint the compreſſion of the wind altogether to anſwer the changeable diſtances of the Sails, which are in the ſame proproportion as their diſtance from the Axis; neither can it eaſily be affirmed, that the force of the Wind by compreſſion doth decreaſe in the ſame proportion, whereby the ſame motion increaſes by the diſtance from the Axis, from whence there would be a compound motion of the diſtance from the Axis, and of the force of compreſſion to be equally diffuſed through the whole length of the Sail or Vane, and therefore the centre of the moving force would be in the middle of the length. Nevertheleſs all things rightly conſidered, I eſteem the centre of this force to which the power is underſtood to be applied, to be not far from the middle of the length of the Vane or Sail, unleſs by chance the Vanes ſhould be ſuch, that their breadth be increaſt by departing, or being placed further from the Axis, for ſo the diſtance being leſſened in the ends of the Sails, the compreſſion of the wind is likewiſe increaſt.

But if you imagine any inconvenience to happen, by the Poles lying upon the little Houſe, and its being turned ſo, as the ſails to be again the wind which they receive; you may on the top of the Houſe in an open place expoſed to all Winds, place an Axis of ſufficient ſtrength perpendicular to the Horizon, about which you muſt place the toothed Wheel parallel to the Horizon, from whoſe turning about, the Mill at laſt is turned; and the breadth of the ſails according to the length of the Axis, muſt be placed in the ſame upper part without the Roof, that the Wind blowing, they may receive the force of it; even as Water flowing, the force is received by the little hands of the Wheels. But becauſe plain even ſails, ſeem leſs apt to continue the rotation, ſince thoſe which are oppoſite to the Diameter, are at laſt equally expoſed to the force of the Wind, and would be forced neither to the right

hand rather than to the left, and therefore the turning round would ceaſe; therefore the ſails ſhould be made a little crooked, or bowing, for by this reaſon they will be made ſo, that the oppoſits will be unequally preſt on, and the Wind will attack with unequal force the convex face of the right, but the hollow face of the left Sail, to wit, it doth as it were remove it ſelf to the Wind, neither is the end of its motion very much oppoſed, according to the bowed direction of the Wind; and I make this hollowing ſo bending every way, that receiving the Wind, it receives its whole force: Moreover the particles of Wind incurring in the two Sails that are next each other, are reflected from the convex of one face to the hollow of the other face, and increaſes the force, or impulſion; but if you pleaſe not to have four, but five Sails, leſt at any time two be oppoſed by the Diameter, I ſhall not deny it. Certain it is, that the length and breadth of theſe kind of Sails help very much; for the larger they are, the more wind they receive, and the longer they are, the further they be from the centre of motion, and have more force: But how the Machine, or Engin, muſt be ſtopt or ſtayed by folding or unfolding the covering of Cloth, that it do not work when the Miller would have it ſtand ſtill, I ſhall not here diſpute. where we are only conſidering the force of moving; neither doth the ſole uſe of this Mill conſiſt in grinding of Wheat,or other Grain, but alſo in raiſing and turning waters another way, that marſhes may be drained, and other things of the ſame kind, which preſent body always moving, they are not tyed to a certain time, even as in the work of grinding, which is not always uſed.

Mecha-

A ... turning ... drave about the wheel, we ... no need of a larger Definition, since almost every ... and hath seen this kind of Engin, although there are ... understand their force rightly, or wherefore they are ... with one ...



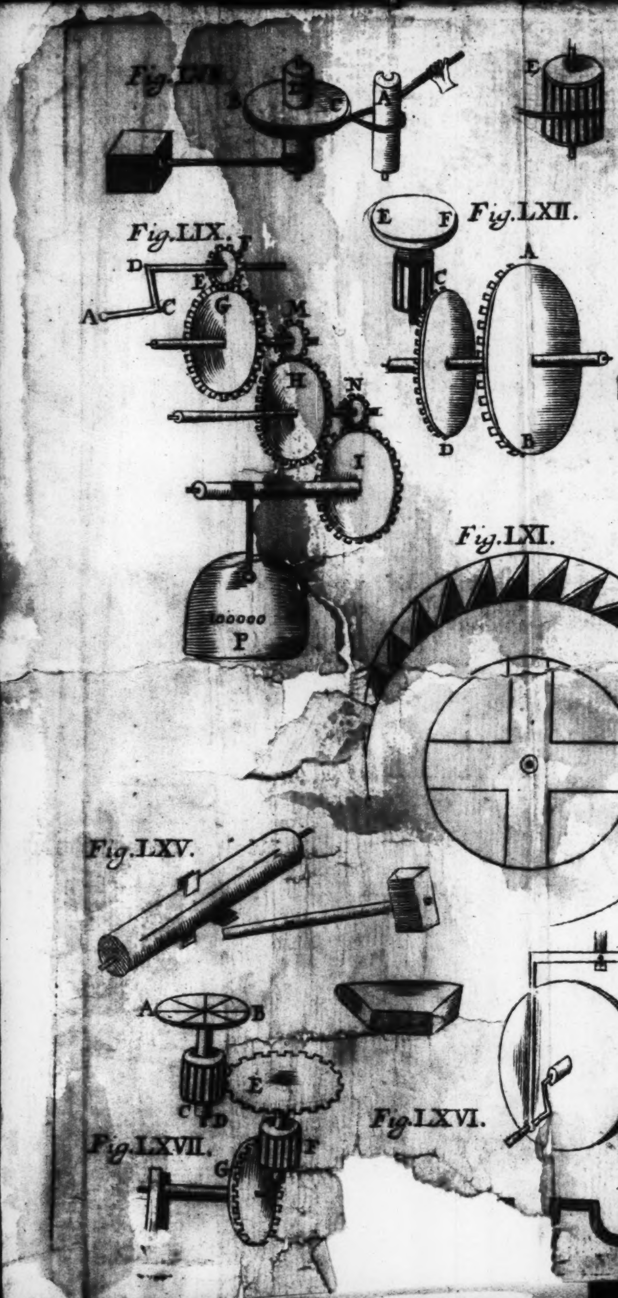


Fig. LVIII.
Fig. LIX.
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Fig. LVIII.

...XII.

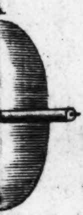
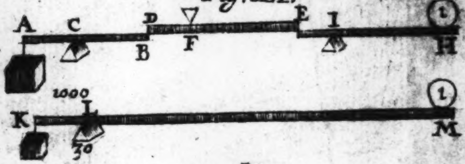


Fig. LX.



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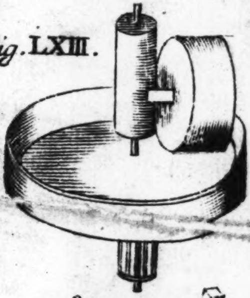

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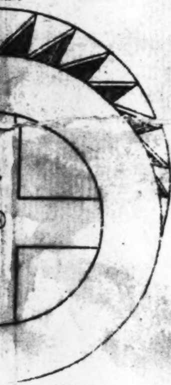
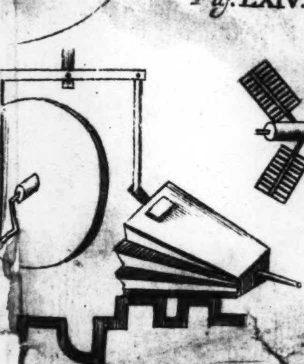


Fig. LXIV.



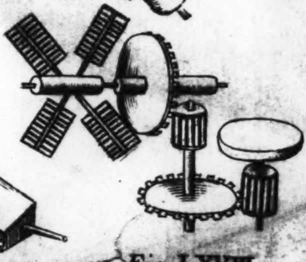


Fig. LXVIII.

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Fig.

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Mechanick-Powers.

OF THE

PULLY, &c.

BOOK IV.

A Pully is an Engin consisting of one or more little wheels turning easily about their Axis, in which a Rope being drawn about the wheel, we draw, or raise a weight; there is no need of a larger Definition, since almost every one knows, and hath seen this kind of Engin, although there are very few that understand their force rightly, or wherefore they are used; and sometimes 'tis wont to be used with one wheel only, and then 'tis called *Monospastos*, or of a double wheel, and is called *Dispastos*, or 'tis trebly multiplied, and is called *Polyspastos*.

PROPOS. I.

A Thorem.

A Single immoveable Pully *neither adds nor diminishes Force.*

Fig. 69. LEt there be a single immoveable Pully A B, so that the wheel only is turn'd about its Axis, and let the snatch block be immovable; I say, that Pully will not en-

encreaſe the force of the Power, properly ſpeaking, ſo that the whole advantage which accrues from ſuch an Engin, is, that the Rope be not worn, and that difficulty ſhun'd which ariſes not exactly from the weight, but from the wearing of the Rope.

The Demonſtration. An Engin then helps not the Power, when the motion of the Power and of the weight is equal; but in the caſe propoſed, the motion of the weight, and the motion of the power are equal, which I thus make appear: Firſt, underſtand the weight in D, and the power in E, draw the Rope, and the power drawing the end of the Rope deſcends in the point G, and in the mean while the weight D aſcends in H, becauſe in both ſites or poſitions the length of the Rope is not changed, D A E will be equal to the Rope H A G, and by ſubſtracting the common ſegment H A E, there remains the lines D H, E G equal; but E G is the motion of the power, H D the motion of the weight; therefore the motion of the weight and of the power are equal, wherefore the weight is neither increaſt nor diminiſht, and the power hath the ſame force only, becauſe if by it ſelf (no Engin intervening) it be joined to the weight, it moves ſo much as the weight; therefore the force is increaſed nothing by this Engin; which was to be demonſtrated.

PROPOS. II.

A Theorem.

A Power is eaſily applied by a ſingle immovable Pully.

LEt there be two Powers; ſuppoſe Men, raiſing equal weights, and let one uſe a Pully, and the other no ſuch Inſtrument, I ſay, the firſt can eaſier apply his force or ſtrength to ſuch weight, than the ſecond; for either the weight will be placed beneath the Man, or above: If the firſt, the endeavour will be ſo, that the tractive force of the Man in ſuch caſe will be poſited in this; that the Man will be a little bent, the force of the Nerves will endeavour to reſtore themſelves to their wonted

wonted rectitude, or to hinder ſuch bending or crookedneſs; therefore when a weight is taken up in this manner, oft-times the endeavour is in the knees and the whole Body; or the weight to be raiſed is placed in an upper place, and then in like manner we muſt have recourſe to the force of the Nerves, but when we uſe a Pully hung in an upper place, we may apply the weight of our body, beſides this kind of force of the Nerves, and oft-times without any endeavour of the Nerves, therefore 'tis not ſo troubleſome.

PROPOS. III.

A Theorem.

Large Pullies *are moſt uſeful.*

Fig. 71. ALthough as I have ſhewn in the firſt Propoſition, that one Pully whoſe Snatch-block is immovable, neither increaſes nor diminiſhes the force of the power; nevertheleſs we have ſaid alſo, it adds to the facility, becauſe that it ſaves the wearing, or rubbing of the Rope, but there is found ſome, although but little reſiſtance, in the Axis of the Pully, which ought to be turn'd about; I ſay, this difficulty will be leſſened, by how much the Orb of the Pully is greater, for than the Semidiameter of the Pully, or Rundle, is as it were a Leaver, and the Semidiameter of the Axis as it were a *Cylinder* in a wheel, or *Peritrochio*; and by how much greater the proportion of the handle is to the *Cylinder*, ſo much the eaſier is the motion; as becauſe there is greater proportion of the line G D, to the radius of the Axis, than of the line G B, the reſiſtance is eaſier overcome, which is made in the circumference of the Axis, while the Pully is turned about it.

There is alſo another conveniency in large Pullies, to wit, that the Rope is not ſo often folded, and conſequently not ſo much rubbed, or worn; but I ſuppoſe alwaies Pullys to be moveable about their Axes, for if they ſhould not, we muſt reaſon otherwiſe.

PROPOS. IV.

A Theorem.

A Man may take up a Weight heavier than himſelf with a ſingle immovable Pully.

THis Queſtion hath been put to me more than once, whether or no a Man can take up, or raiſe a weight heavier than himſelf, with a ſingle immovable Pully (I always underſtand the Snatch-block immovable) or whether a man that weighs 150 pounds, can raiſe a weight of 200 pounds? But I devide the caſe, to wit, either a man ſo ſingly ſtands, that the force of his weight, or gravity, only inſiſts on the Pavement, or his Knees, and his whole body ſo indeavours, that the force of this endeavour adhears to ſome other Body; if this ſecond happen, a man may elevate a weight heavier than himſelf, to wit, becauſe, beſides the weight of the man which may be all applyed, there may be alſo a contrary endeavour from the reſiſtance of the Nerves, ſo that while I would take up one, with the *Pully* I take up more; ſome Knees endeavour ſo, that they cleave to Benches, or Formes, and lift up the Benches together with them, whence from ſuch endeavour an union is made of the Benches with the Man; that I may better explain my ſelf, ſuppoſe a man has 50 pound weight upon his Feet, and both his hands to lay hold on a Rope faſtned in an upper place, if the weight on the other part be very great, the man may by hanging on the Rope lift up his Feet, and elevate or raiſe the weight of 50 pounds, in which caſe, beſides a weight equal to himſelf, he may elevate 50 pounds.

But if he ſingly ſtands on the Ground, experience teaches us that he will only elevate 150 pounds.

But we muſt argue otherwiſe in drawing of weight inſiſting on the ground, or on an inclined plane, for ſince weight doth not preciſely reſiſt an *Horizontal* motion, a certain rule can ſcarce be made; for it depends on the evenneſs of the body on which the weight ſtands, or lies.

PRO-

PROPOS. V.

A Theorem.

Many immovable Pullys *neither increase nor diminish the force of a* Power.

Fig. 72. LEt the several Pullys be E F G, whose Snatch-blocks are immovable; I say, although we use them altogether, the force of the power is neither augmented nor diminisht: For let the power be in A, and the weight in C, draw the Rope in B, and the weight ascends in D.

The Demonstrat on. Forces of Powers are neither diminisht nor increased by an Engin, when the motion of the power is equal to the motion of the weight, but in this case it thus happens; for when the Rope A E F G C, is the same by supposition, as the Rope B E F G D, they will be equal, and the common segment A E F G D being taken away, there remains D C equal to A B; but A B is the motion of the power, and D C the motion of the weight, therefore the motion of the power, and of the weight are equal, and therefore the forces of the power are neither increast nor decreast, which was to be demonstrated.

PROPOS. VI.

A Theorem.

A Weight hung to a movable Pully *its half part is Diminished.*

Fig. 73. LEt the Pully be A, and its Snatch-block movable, and a weight hung to it, and the power in D; I say, the weight will be lessened an half part, suppose the power to be so moved, that the Pully A ascend to E.

Tha

The Demonstration. That the Pully A be placed in E, the power ought to be moved as much as the length of the Chords C F, G D, for from the point C to D, is the ſame diſtance as between F and G; but C F, G D taken together, are double the ſpace A E, to which the motion of the weight B is equal as appears, therefore the motion of the power is double the motion of the weight; but (by the firſt principle of Mechanicks) as often as the motion of the power is double the motion of the weight, the whole force of the power is doubled; therefore in our caſe the force of the power is doubled in order to ſuch weight, or which is the ſame, the weight is diminiſht an half part, which was to be demonſtrated.

But if in ſtead of the Hook C, there be added one power which ſhall be equally moved with the power D, we ſhall find by tryal only an half part of the weight, in the ſame manner as if they bore two weights equally diſtant, hung to a Beam or Leaver.

PROPOS. VII.

A Theorem.

A Power *applied to a moveable* Pully, *diminiſhes an half part, in reſpect of a Weight hung on one end of a Rope.*

Fig. 74. IF in ſtead of the weight B being hung, a power be applied to the ſame Pully, and the weight hung to the Rope D, I ſay, the force of the Power is diminiſht an half part.

The Demonſtration. As I ſhewed before, the motion of the weight will be double the motion of the power, and therefore (by the firſt principle of Mechanicks) the forces of the power are leſtned, and the forces of the weight increaſed; which may likewiſe be ſaid of two weights, to wit, as when the weight B of 100 pounds is made in *equilibrio* in the point D, or which way ſoever the Rope G D ſhall require 50 pounds.

Corol-

Corollary.

Hence it follows, that an immovable Pulley is a Leaver of the first kind, of equal Armes, and a movable one is a Leaver of the second kind, or in like manner of the third kind, of equal Armes.

PROPOS. VIII.

A Theorem.

If to move the Wheels of a Dial, or Clock, for 12 Hours, there be required a weight of 50 pounds, and the weight descend 20 feet, keeping the same descent, a weight that shall move the Clock 24 Hours will require to be 100 pounds.

THis proposition which may easily be deduced by the *Corollary* of the precedent proposition, because of the commonness of its use, may be proposed in this manner; suppose a common Clock that requires a weight of 50 pounds to keep it in motion, and suppose the place where the weight descends to be 20 foot only, and this descent serves for 12 hours; and we would, keeping the same descent, have a weight to serve for 24 hours, I desire the magnitude of the weight; I say, the weight required must be 100 pounds.

The Demon. Suppose the motion of the Clock and its resistance, to be after the manner of the motion of the other weight, 'tis certain by the supposition that the resistance of the Clock for 12 hours, is less than of a weight of 50 pounds being movable 20 feet; but the motion of the Clock for 24 hours is double of that which is made in 12 hours, and in like manner a weight of 100 pounds as movable 20 feet, is double of a weight of 50 pounds that moves the same space, therefore the motion of the Clock for 24 hours will be less than a weight of 100 pounds moving 20 feet, and will be exceeded by the same excess.

And the way to fit that weight is easie, for if it be required precisely to move in a time double to that wherein it did move, it may be done with no charge by help of a Pulley, in that manner as is shewn in the 7th Proposition, *viz.* If the Rope be fastned firmly at one end, and the other end join close to the Cylinder of the Clock.

But if another less proportion be required, to wit, as 2 to 3, or as 3 to 4, the Diameter of the Cylinder on which the Rope goes about in the Clock must be lessened, according to the proportion given reciprocally, that is, if for example it be required, that the weight of the Clock should move 18 hours, when before it moved only 12 hours, the Cylinder must be lessened according to $\frac{1}{3}$ part of its Diameter; but if there be required a quadruple proportion, two movable Pulleys must be made use of. Lastly, If a proportion much greater be required, add one Wheel to the Clock.

PROPOS. IX.

A Theorem.

In Dispasto, *or two* Pulleys, *if the cord of a movable* Pulley *be only turned about the Wheel, and is not fastned to its Snatch-block, or weight, but to the immovable point, the power will be only doubled, which draws by the other end.*

Fig. 75. BEcause there are many ways which Ropes may be put about Pulleys, from whence follow several augmentations of a power; I will undertake to explain this in the first place, to wit, if one end of the Rope A D C E be fastned in the unmovable point A, or to any other point, as the point B, and be turn'd about the Pulley D, then about the Pulley C, and be drawn by the end E; I say, the force of the power placed in E, with respect to the weight hanging at D, is doubled.

The Demonstration. The point E is equally moved with the point

point F (by the first of this) but the point F is moved with a double velocity to the weight hung in D, (by the 7.) therefore the point E is moved doubly swifter than the weight D; but E is the place of the power, therefore the power is moved doubly swifter than the weight, and (by the first principle of Mechanicks) the force of the power E is doubled: Which was to be shewn.

Secondly, Let the end E be firmly fixt, or unmovable in the point E, and draw the Rope upward from the power placed in the point A; I say, in like manner the force of the power is doubled, and the Pulley C is useless.

The Demonstration. When the Segment of the Rope ECF in this case is immovable, it will be the same as if the Rope were fastned in the point F, and one Pulley used only, but (by the 6th of this) one Pulley placed in this manner, doubles the force of the power, therefore also in this case, the forces of the power are doubled: Which was to be shewn.

Corollary.

Hence it follows, that if the power be D, and the weight in E, the end of the Rope fixt in the point A; I say, that in this case, when the motion of the weight is doubled, the force of the power is lessened.

PROPOS. X.

A Theorem.

In Dispasto, *or two Pulleys, if the end of the* Rope *be fastened to the movable* Snatch-block, *and the rope be turned about the same wheel, the power will tripled, or threefold.*

Fig. 75. LEt the end of the rope be fastened in the point I of the movable Snatch-block, then turn it about the wheel of the immovable Snatch-block B; and again, turn

it about the wheel of the movable Snatch-block I, and let the power be in the point C, drawing the rope upwards. I ay, the force of the power is tripled.

The Demonstration. Suppose the power C so to be moved, that the Pulley I, touch the Pulley B; In this case there is left only so much of the rope as is required to compass both the wheels, to wit, as much as the portion F B E, and G H I, and the motion of the drawing power from C is equal to the rest of the rope, or to the parts A E, F G, H C; but those parts taken together, are triple the motion of the weight, to wit, the line I E, therefore the motion of the power is triple the motion of the weight, therefore the forces of the power are tripled: Which was to be shewn.

PROPOS. XI.

A Theorem.

In Tripasto, *or three* Pulleys. *If two* Pulleys *are immovable, and one only movable, the power is tripled.*

Fig. 76. LEt there be three Pulleys, wherein two of them A and B are immovable, or immovable in the Snatch-blocks, and let the rope be fastned in the point C; then turn the rope about each wheel, as you see in the figure, and let the weight be D, and the power in E: I say, the power is tripled.

The Demonstration. The point E is not more moved than the point F, and therefore the Pulley B is only used for conveniency sake. But the point F (by the 10th of this) is moved triply, or threefold swifter than the weight D, therefore in this disposition the power is triplicated; which was to be shewn.

But the end of the rope C could not be fastned to the upper Snatch-block, otherwise one of the upper Pulleys would have been useless.

PROPOS.

PROPOS. XII.

A Theorem.

In Triſpaſto, *or three Pulleys, two of them being movable in the ſnatch block, quadruplicates the power.*

Fig. 77. IF there be three Pulleys, wherein the two lower ones A B are moveable; I ſay, the Power in C in this caſe is Quadruplicated.

The Demonſtration. Underſtand the power C to be ſo moved in drawing the Rope, that the Snatch-block A B, touch the Snatch block E, there remains about the Pulleys a Segment of the Rope equal to the Segments D E F, I B K, G A H; the reſt are drawn by the Power, and meaſure the Motion of the Power: But the Segments D I, L G, F H, C K are quadruple the ſpace L G, therefore the Motion of the Power is quadruple; which was to be ſhewn.

Notwithſtanding, becauſe this kind of drawing upwards is inconvenient; a Pulley ſhould be added in the Upper Snatch-block, and then its force will be quadrupled, for the Pulley is only added for conveniency.

PROPOS.

PROPOS. XIII.

A Theorem.

If the Lower Snatch-block be moveable, and the Power draw upwards, the Power is so many times multiplied as are the drawing of the Chords.

Fig. 77. LET the Snatch-block A B be movable, and the Power C draw upwards; or that the Proposition may be more Universal, let it draw against the immoveable Snatch-block, then the Power is multiplied so many times, as there are drawings of the Chords, because then either the end of the Chord being fastned, is in the upper place, and being drawn, the pairs will be doubly more than the lower Pulleys; but the lower Pulleys double the Power, and by the demonstration, if there be one below, there is no need of the upper one, as is shewn in Prop. 6. and the force is doubled according to the proportion of drawing. If there be two below, and one above, 'tis shewn in the precedent Proposition, that the power is quadruplicated; and so of the rest.

PROPOS. XIV.

A Theorem.

If the lower Snatch-block be movable, and the power draw downwards, the force of the power is so many times multiplied, as there are drawing of the chords, one less.

Fig. 75. 'TIS shewn that the force of the power in F is the same as in E, but if the power be in F, and

and its force multiplied according to the number of drawings, to wit, triplicated, and in E there be added one drawing of the Chord; this drawing of the Chord, which is added, increases not the force, therefore ought not to be computed.

PROPOS. XV.

If the lower Snatch-block be movable, and the rope be fastned to the movable Snatch-block, any lower Pulley doubles the power, and renders one upper power only equal to the weight.

LEt there be any number of Pulleys in which the Snatch-block of the lower is movable, to which fasten the end of the Rope; I say, If there be one upper Pulley, the power is equal to the weight; if one be added below the force of the power is doubled, and so the power will be triplicated, but the rest of the upper ones add nothing, that is, if there be two upper ones, the power will remain tripple of it self; if another be added below, it will be quintuple, and so on, which are all demonstrated, particularly in the foregoing Propositions.

PROPOS. XVI.

If the lower Snatch-block be movable, and the rope fastned to the upper, as many Pulleys as are below, so many times the power is doubled, the upper ones serve only for conveniency.

IN any number of Pulleys in which the Rope is fastned to an immovable Snatch-block, the power is so many times doubled,

bled, as there is lower Pulleys, or in a movable Snatch-block: That is, if only one be in the movable Snatch-block, the force of the power is doubled; if two, 'tis quadrupled; if three, 'tis equal to six powers, and so on, so that no proportion ought to be had of the upper Pulleys, or of their being in an immovable Snatch-block.

The Demonstration. 'Tis shewn in Prop. VI. that 'tis so in one Pulley. In Prop. IX. 'tis shewn to be so in two Pulleys, to wit, that the power in both cases is doubled. In Prop. XII. in three, or more Pulleys 'tis the same; the like proportion may be demonstrated in others.

Whatsoever is shewn concerning the raising of weight upwards, is to be understood of any other motion, whether Horizontal, or any other, to which weights resists; also of any resistance that we undertake, to overcome by Pulleys.

Also as we compare the power with the weight, we may in like manner compare two weights between themselves; likewise if you place the power in the place of the weight, and in like manner, if the weight obtain the place of the power, the weight will be increast with respect to the power, or the power diminisht, which words are all of one signification; and the moving power may obtain the place of the weight, as often as the forces are abounding; but a most swift motion is produced in a weight, which simply from a power cannot be produced without an Engin, because the power cannot move it self with so much velocity; which principle is to be understood in all Engins.

PROPOS. XVII.

To dispose Pulleys *so that according to the number of the* Pulleys, *the power may always be increased continually in double proportion.*

Fig. 78. THe increase of power by Pulleys hitherto treated on, seems to proceed only according to Arithmetical

metical proportion, ſo we ſhew in the precedent propoſition, that according to the number of Pulleys placed in the moveable Snatch-block, the force of the power is doubled; now we will inſtitute another diſpoſition, wherein if there be only one Pulley, the force of the power will be doubled, if two, quadrupled, if three, it will be octuple, if four, the power will be equivalent to ſixteen, and ſo of the reſt.

Suppoſe a weight to be raiſed being faſtned to a moveable Pully B, and let one end of the Rope be fixt in the point G, and the other end of the ſame Rope reach to the Snatch-block C, in like manner let another Rope F C D be firmly fixt in F, and the other end fixt to the Snatch-block D; let there be a third Rope E D H, one end of which faſten well in the point E, and let the power be in H; I ſay, the power in H of it ſelf being equal to the weight, being ſo diſpoſed, is octuple of the weight.

The Demonſtration. 'Tis ſhewn (at Prop. VI. of this) that the power in H is moved with a double velocity of the Snatch-block D, and the Snatch-block D doubly ſwifter than C; and C doubly ſwifter, or as ſwift again as B, therefore H is moved eight times ſwifter than the weight, and (by the firſt principle of Mechanicks) will have eight times greater force in reſpect of the weight; therefore 'tis ſufficient that the power be ſuboctuple of the weight to be in *equilibrio* with the weight,

Or it may be demonſtrated by any Leaver, for a Pulley diſpoſed in this manner, is a Leaver of the ſecond kind, in which the weight is preciſely in the middle between the power and the prop, or Centre.

PROPOS. XVIII.

A Theorem.

By Pulleys any weight may be moved by any power.

FIrſt, If the power be never ſo little greater than the weight, it may be moved by any Pulley that only helps the application, but if it be equal, and the Pulley diſpoſed after the

second manner, the weight will be more easily moved; but if the power be less, as if it be to the weight as one to eight; eight Pulleys disposed in this second manner, or eight Pulleys disposed in two Snatch-blocks, will easily overcome the whole resistance of the weight; to wit, if there be a greater proportion of the motion of the power to the motion of the weight, than of the weight to the power.

Mechanick-Powers.
OF THE
SCREW.

BOOK V.

A Screw is a Cylinder wrought in one or more solid Spires, or Helices swelling out, as appears in the figure.

Fig. 79. AND the use of it is common, for 'tis put into another concave cylinder, cut in like manner into concave Spires, so that the convex Spires or Helices of the former Cylinder, fit to the concaves which are put upon them. The concave Cylinder sometimes is fixt and immoveable, and in this case, the Screw besides its circular motion, hath also a right motion, whereby the whole Cylinder goes forth. Sometimes the Screw is immovable, and the concave Cylinder is only moved, and commonly a simple Cylinder is added to the Screw, into which a handle is grafted or fixt, as in A B the handle B C is adjoyn'd, that it may be moved round more easily; hitherto Authors have recalled the Screw to the Wedge, and the Wedge to the Leaver, or to the motion of a weight on an inclined plane, as if you understand D E to

be

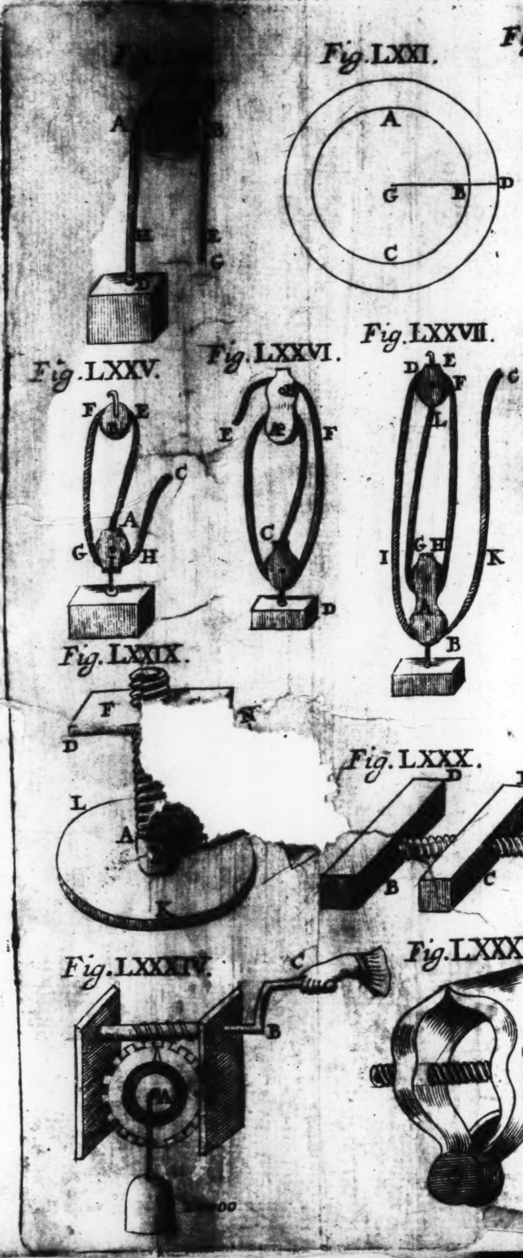
Fig. LXXI.
A
G
B
D
C
A
B
H
E
G
D
Fig. LXXV.
F
E
C
A
G
H
Fig. LXXVI.
E
F
C
D
Fig. LXXVII.
D
E
F
L
C
G
H
I
K
B
Fig. LXXIX.
F
D
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A
K
Fig. LXXX.
D
B
C
Fig. LXXXIV.
C
B

Fig. LXXII.

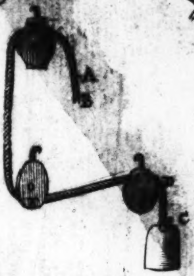
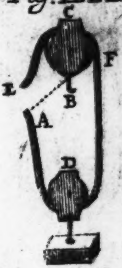


Fig. LXXIII.

Fig. LXXIV.



XXVII.

Fig. LXXVIII.

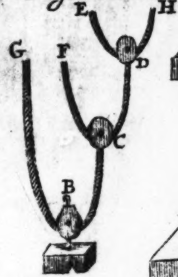
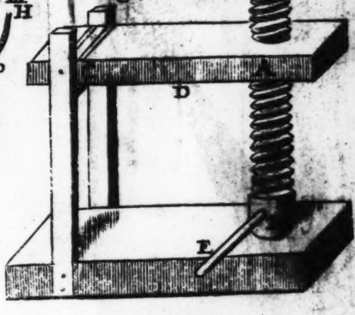
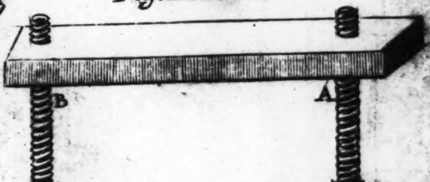


Fig. LXXXI.



XX.

Fig. LXXXII.



g.LXXXIII.

be the weight, and it be moved round in the Orb, ſo that it aſcend according to the Spire of the Screw, inclined to the Horizon, or if the Wood D E be immovable, the Screw it ſelf being turn'd about, which is conſider'd by the manner of a weight, its aſcent will be by the inclined plane of the Spires of the concave Cylinder F G; but theſe conſiderations are ſuperfluous and unprofitable, when more immediately the force of the Screw may be meaſured from the firſt principle of Machines, than by ſuch reduction.

PROPOS. I.

A Theorem.

To explane, and meaſure, the force of the Screw.

Fig. 79. LEt the Screw be A B, furniſht with its handle B C, for alſo in leſſer Screws of Iron which are made uſe of to ſtrain ſomething, there is added a head furniſht with a notch or cleft, that there may be put in ſomething of Iron, which may obtain the force of a handle; And let the power be applied in the point C, and underſtand one circumvolution to be made, or the circle C K L to be deſcribed in the mean while the weight aſcends, from one circumvolution of the Spire to another, to wit, as much as is the line N O. An interval, or ſpace, equal to the line N O comprehended between the two Spires, is found 100 times in the circumference C K L; I ſay, that it may be in *equilibrio*, there is required ſo much power as is only ſubcentuple of the weight, that is, if the weight be 100 pounds, it requires a power only equal to 1 pound.

The Demonſtration. 'Tis then in *Equilibrio*, when the motion of the power is to the motion of the weight, as the weight it ſelf is to the power, but in our caſe the motion of the power is centuple the motion of the weight, and the weight an hundred fold of the power it ſelf, therefore 'tis in *Equilibrio*, whence if the power be a little greater or more than one pound it will overcome the reſiſtance of the weight.

Corollary.

If the power be applied to the wood D E, ſo that it move downward by a right line, and not circular, notwithſtanding it will compel the Screw to move circularly, and let the weight be in C, the power requires to be centuple of the weight to move it. But if the wood D E be moved circularly, and the weight aſcend upwards in a right line with the Screw; as if you feign the weight to be B; the whole circle deſcribed by the wood would be compared with the circumference of the line N O, which meaſures the aſcent of the weight in each circulation.

PROPOS. II.

A Theorem.

The divers uſes of ſingle Screws.

Fig. 80. THE uſe of ſingle Screws are various, and for the moſt part they are uſed to ſtrain, as appears in the 79th Figure, in which the Screw A B is faſtned in the hole B, alſo 'tis furniſht with its Spires, but the hole C is ſingle, and conſiſts of no Spires; while the head of the Cylinder arrives in C, and the Screw is turned about, the woods B D, C F, will come, or meet together, and the force of the power will be increas'd according to the proportion of the circle deſcribed by the end of the handle A E, to the interval of the Spires, or Helices.

And the ſame effect follows whether the wood B D be made immovable, and ſo the wood C F, come to that, or the contrary.

The ſecond kind is, *Fig.* 81. when the Screw is at one end, and the wood to which 'tis faſtned, is at the other end, and is immovable, and then the power will be mixt, to wit, of the Screw and Leaver, as in this figure, if the Screw A B, be ingrafted to the wood A C, in the point A, and the piece of timber to which 'tis ingrafted be fixt in the point C; and the weight,

weight, or that which resists the pressing, be in the point D, C A will be a Leaver of the second kind.

And that you may measure the force of this Engin, suppose it a Wine-press, and let the beam C A be equal to a weight of 200 pounds, that is, if it lies on a parcel of Grapes, it will make the same compression as 200 pound weight will make; and let the Screw be so made, that each spire be distant from one another one inch, and the handle B E 7 feet, so that its whole circumvolution will be 22 feet, or 264 inches, and let the force of the man that presses, be equal to 100 pounds; I say, the man alone hath so much force to press the Grapes, as hath the weight of 52800 pounds; the reason is clear, for while the man runs over 22 feet, or 264 inches, the beam A descends only one inch, and the weight D, which is in the middle of the Leaver A C, is only moved half an inch, therefore the force of the power is increased, according to the proportion of 264 to $\frac{1}{2}$, or of 528 to 1; but the power is 100, therefore the force of the man, using this press, will be equivalent to 52800 pounds; which was to be shewn.

Fig. 82. The third manner will be, if you make use of 2 Screws, which are moved together, or successively after each other, and one in respect of t'other, hath the proportion of a Prop, or Hypomoclion; as if the Screw A be moved, the Screw B not being moved, the point B will be the Prop, with respect to the Leaver A B, which belongs to the second kind of Leaver.

Fig. 83. To this kind of power are recalled the Vices which Iron-smiths use, likewise the Presses which Printers use, and many other Instruments, whose forces we may measure by the same principles.

PROPOS. III.

A Theorem.

Of Compounded Screws.

Fig. 84. I call that a compounded Screw, whose convex Cylinder is not ingrafted, or fitted, into its corre-

spondent

ſpondent concave, but is mixt with other powers. And firſt, if the Helices of the Screw be fitted to a toothed wheel, 'tis call'd an infinite Screw, or moving in *infinitum*, the forces of this power are wonderful, for ſuppoſe a wheel to conſiſt of 50 teeth, alſo let the Axis be A, about which the rope goes round; and let the handle B C, be to the Semidiameter of the Axis, as 4 to 1, and let the power of the man be equal to 100 pounds; I ſay, the man being furniſht with ſuch an Engin, is in *Equilibrio* with a weight of 20000 pounds, and the man will be equivalent to 200 men.

The Demonſtration. The handle B C ought to make 50 circumvolutions, while the wheel only performs one, becauſe that every circumvolution of the Screw impels only one tooth: Therefore while the handle B C is turn'd round 50 times, the Tympane A is only once turn'd about; but the circulation of the handle is to the circulation of the Tympane, as 4 to 1, therefore the motion of the power applied in C, is to the motion of the weight, as 200 to 1, therefore by reciprocation, the power as of 1 pound will be in *Equilibrio* with a weight of 200 pound, or as 100 to 20000, which was to be demonſtrated.

But if inſtead of the Tympane A, you uſe another Screw, to whoſe wheel the ſame number of teeth ſhall anſwer, one man will be equivalent to 10000 men. If you make uſe of three Screws in the ſame manner and order, with wheels anſwering to them, one man will be equivalent to 100000 men.

Nevertheleſs, ſcarce any Engins are ever made ſo ſtrong, but in practice they become unuſeful, becauſe, that either the ropes break, or that which they are faſtned to, is not able to ſuſtain, or the teeth, or other parts break, the weight being ſo extraordinary.

This Engin is moſt uſeful, as often as the motion is to be diminiſht, as when, for example, we have a wheel in a Clock, which is turn'd round once in every hour, if you deſire a motion 12 times ſlower, the Axis of this firſt wheel, muſt have a Screw, to whoſe ſpire the teeth of the other wheel, muſt be ingrafted, which muſt have 12 teeth, and ſo you will have a motion 12 times ſlower; ſo if in a Clock you have a Wheel, or Axis, which is turn'd about twice in a day, which is furniſht with a Screw, and anſwers to a wheel, having 59 teeth,

this

this ſecond wheel will be once turn'd about in 29 days and ½, which is the period, or circuit, of the Moon, and ſo of the reſt. He that deſires more concerning the Screw may conſult *Ubaldus.*

I ſpeak not here concerning a concave Screw, which is one among Hydraulic Engins, and which properly belongs to an inclined plane; the benefit of a Screw are theſe. The firſt advantage is, that the motion of the weight is more diminiſht by one ſpiral line, than by many toothed wheels. Secondly, without any ſtay, although the power be relinquiſht, the weight ſcarcely falls back again, and therefore muſt remain where it is.

The more Helices there are in a Screw, and the more oblique, and the longer that the handle is, the eaſier the weight is moved; and in a concave Cylinder, (or the mother) the more Helices there are, the leſs the Screw ſuffers, for when there are many Helices, the weight is diſtributed in them, which would preſs, or lye on one only.

Fig. 85. To this Engin we may refer a certain invention obvious enough, which we do not uſe to increaſe the force of power in order to motion, but only to ſuſtain a weight; For if about any Cylinder there be made a hollow ſpire about which a rope is turn'd, if you hold the rope but ſlightly, or preſs it again the Cylinder, the weight, although it be great, will be ſtayed by the Ropes, being adjoin'd to the Cylinder: Theſe Channellings, or Hollowings, are uſeful if any one be minded to deſcend from a high Tower without danger, and that ſwiftly, or ſlowly, according to pleaſure.

Awgers, Wimbles, and Piercers, are referred to the Screw, which enter the eaſier, by being made ſharp in the nature of a Screw, as experience teaches, in great Awgers, with which Pipes are boared to convey Water from Fountains, becauſe its apex repreſents the figure of a Screw, which of its own accord enters the Wood ſo that there is but little need of Force.

Mecha-

Mechanick Powers.

OF THE

WEDGE.

BOOK. VI.

ALthough the Wedge be a simple Instrument, and therefore of some, is scarcely ascribed to the number of Engins, neverthelesss it is of such force, that deservedly it finds a place here.

The Wedge is a triangular Prisme, whose two rectangles, end in a common right line.

And that it may be useful, it ought to be made of solid matter, as of Iron, or Wood, and such like.

Its use is in the cleaving of Wood, parting of Stones, and dividing other bodies that may be cleft, or cloven; a slit being made in the body, the edge of the Wedge is thrust in, and and a strong percussion being added, forces in the Wedge.

PROPOS. I.

A Theorem.

The force of the Wedge explained.

Fig. 86. DIvers reasons are alledg'd for the force of the Wedge, and first from *Aristotle*; in Question 17, the Wedge is recalled to a double Leaver of the first kind, in this manner, to wit, let the Wedge be A B C, *Aristotle* understands

ſtands the line A B, as a Leaver of the firſt kind, whoſe prop is D, the power in A, and the weight in B, to wit, in the end, or cuſp of the Wedge: In like manner let B C be another Leaver, whoſe prop is in E, the power in C, the weight in B.

Notwithſtanding, this explication is altogether contrary to the proportion of the Leaver; for by how much greater the diſtance is of the power from the prop, the greater is the force of the power, in other like caſes; but in this caſe it is not ſo, for if the Wedge be made ſhorter, and the power be in K L, and not in A, nevertheleſs the force of the Wedge will be the ſame: I ſay, the ſame of the leaver C B.

The ſecond is falſe, that the Wedge touches the Body to be divided with its point, or edge, becauſe, that for the moſt part the extreams D and E only touch; neither when we meaſure the force of the Wedge, do we regard the proportion which is found between A D and D B, but how much the ſharper the Wedge is, or the leſſer angle it contains, the eaſier it divides.

Whence *Ubaldus* in his Mechanicks imagines, that if the Wedge be recalled to a Leaver, 'tis to be explicated by a double Leaver of the ſecond kind, whoſe common prop is in the edge, or point B, the power in A and C, but the ſame inſtances occur as before; I add moreover, that a Wedge may want a point, and nevertheleſs be as apt to divide as it was before; ſo that the inclination of the planes remains the ſame, touching in the points in which the body is to be cleft.

Fig. 87. Wherefore others recal the Wedge to an inclined plane, as if the body to be lifted up be A, under which the Wedge B is laid, that body being moved upon an inclined plane, for 'tis all one, whether the body be drawn upon the plane, or the plane move under it, for to aſcend 'tis thought the ſame; therefore there are in the Wedge two inclined planes. This conſideration is not abſurd, nevertheleſs, I contend that the whole difficulty remains, to wit, that the whole doctrine of inclined planes is alike hard, labouring under the ſame principle, wherefore

I ſay, The reaſon why the forces of the power are increaſed by the Wedge, is, becauſe the power is moved much, and the weight but little, or the greater motion of the power is compared with the leſſer motion of the weight, and are joyn'd together.

Which I shall shew, as in the *Fig.* 86. let the Wedge A B C be very sharp, which by one or more percussions runs into the wood, the space B F, in the mean while that the parts of the wood are separated from one another according to the space D E; if the Wedge contain an angle less than 60 degrees, B F will be greater than D E, and the power is moved according to the line B F, and the weight according to the line D E, wherefore secluding percussion which way soever, if the power simply impel the Wedge, its forces are increased, according to the proportion of the line B F to the line D E.

PROPOS. II.

The sharper the Wedges are, the greater force they add to the power.

Let there be any 2 Wedges, whereof one is more acute than the other; I say, that which is most acute, confers the greater force to the power; for by how much the motion of the power, is greater than the motion of the weight, it hath greater force in respect to that weight. But a more sharp Wedge is such, that it requires a greater motion of the power in respect to the motion of the weight, for in two triangles, having an equal base, that which hath the angle opposite to the base most acute, will have the longest side: But in the Wedge, the base measures the motion of the weight, and the side the motion of the power, therefore Wedges most acute are most powerful.

Corollary.

A Wedge whose angle is greater than an angle of 60 degrees, rather decreases than increases the force of a power.

PROPOS. III.

A Theorem.

Divers kinds of Wedges.

ALmost all Instruments which Artificers use to divide, or cut with, are recall'd to the Wedge, as all sort of edge tools, Swords, Pen-knives, Nails, Axes, Hatchets, are Wedges, for neither is it essential to a Wedge, that the percussion of another body be forced between the body to be divided, for it may either be simply impell'd, or from a force conceived from the leading motion to divide it; Awgers, and Piercers contain a Wedge.

Of Percussion, or Smiteing.

PROPOS. IV.

A Theorem.

Experiences of Percussion.

I Being in company, some years ago, with my Ingenious friends Mr. *Bankes*, the King's Master Carpenter, and Mr. *Morris Emmet*, the King's Master Bricklayer, since deceased, among other things that pass'd in our discourse, Mr. *Bankes* was pleased to say, that he thought there could be no reason given of the force of Percussion, nor no comparing the proportion of weight pressing a Nail, or such like thing, entred in a board, or Timber, to a blow smitten on the same thing. Indeed the saying was very difficult and abstruse, yet I remember I told him, that the learned and Reverend Dr. *Wallis*, and

Cassatus had writ something concerning it, and also the learned *Dechales*, whose principles I design to follow.

Aristotles 19th Question touches lightly on the force which is produced from Percussion; nevertheless, he explicates nothing further, and as I may say, only proposes a difficulty, to wit, that although a great weight be laid upon an Ax or Wedge, yet it conduces little or nothing to cleaving, but that a blow smitten with great velocity, affects much. Then he seeks how much gravity this motion adds; to the better understanding whereof, in the first place, I shall refer to experience.

The First *Experience* then shall be, that that Percussion is greatest, whose motion is swiftest, from whatsoever cause the same motion proceeds, whether it be circular, or right, 'tis little different. From whence it comes to pass, that a Hammer, or Mallet, furnisht with a longer handle, makes a stronger blow, because that power can impress a swifter motion, for if it be moved with equal velocity, whether it be furnisht with a longer or shorter handle, the percussion would be equal; also thence I think may be concluded, that lasting motion adds nothing to percussion, unless there were a disposition to swifter motion. And therefore, if the Hammer should be moved equally about some Center, it would not smite stronger after a lasting motion than after some short motion. Also 'tis clear, that when something is smote with a Staff, or a Sword, the stroke is stronger about the end, because then the staff is moved about the hand, as about a centre, whence the motion is stronger about the end, I say about the end, yet not in the end, by reason of another proportion.

Secondly, A greater body although it be moved with equal velocity, with a lesser, produces notwithstanding a stronger blow; for 'tis certain, while two bodies of the same matter and divers magnitude fall from on high, they descend almost with equal velocity, so that the difference is very small, to wit, so much only as is begat in the resistance of the air proportionally in the lesser body to the greater, neverthless, the greater body impresses a stronger blow, which effect cannot be only attributed to the greater gravity; for let there be a stake stuck in the ground, and let two bodies descend from an equal height, one of 100 pounds, the other of 200 pounds, 'tis certain that there will be a stronger impression from the

second

ſecond, which cannot be attributed only to the gravity ſimply taken, for if this ſecond body be put on the ſtake and gravitate on it, or ſhould fall on it from on high, the impreſſion from a body leſs heavy, would not be ſo much. Therefore a heavy body falling, makes a greater ſtroke than a lighter body, and this impreſſion ought not to be attributed only to the greater gravity.

The Third Experience. While a body is moved about ſome centre for a continuance, 'tis eaſier ſtopt or ſtay'd if you lay hold of it by the end, than by any other part nearer the Centre, which is to be underſtood if it be hinder'd before the motion, or in the beginning of the motion, for if you wait till the motion be engender'd, it will be otherwiſe. And the reaſon of the firſt, is obtain'd from the proportion of the leaver; the reaſon of the ſecond ought to be, becauſe the motion is greater in the end, and conſequently a greater *impetus* is acquired.

The Fourth Experience. The ſtrongeſt blow of a Sword is not about the point, nor as ſome think about the Centre of gravity, but between the point, and the centre of gravity; yet in general 'tis true, that a body that is moved, having the greateſt part of its weight about the end, a ſtronger blow follows than if it proceed from one continuance, wherefore ſome make a little channel within the Sword, and include Mercury therein, which conveys the force of percuſſion to the point, and makes the ſtroke ſtronger. Perhaps, while a body is extended in one order, 'tis moved more difficultly, and therefore its velocity is not ſo great, and conſequently its ſtroke not ſo ſtrong.

Fig. 83. *The Fifth Experience.* While a body ſmiteing deſcends, it cauſes as great a ſtroke, if only one part of it fall on the ſubjected body, as if the whole body fell on it; that is, if 2 equal bodies A and B, fall from the ſame height, the firſt whereof ſmites the ſtake C only with ſome part of it, but the other according to its whole loweſt ſuperficie, yet an equal ſtroke follows, which I have found by experience, that I might confute the opinion of ſome, eſteeming the Air ſqueez'd between the 2 bodies, to confer much to the blow, yea, they will have all cutting or cleaving to be from air included within the Pores, being violently impulſed from the dividing body, for they will have air to be moſt ſharp, and conſequently moſt apt to divide.

PROPOS. V.

A Theorem.

Divers measures of Percussion.

Fig. 89. 'TIS hard to measure percussion that is made by a living power, since it depends on force, and free and voluntary endeavour, and hath the proportion of the body moving, or smiteing, for although a greater Hammer effects a stronger blow in other things of the like nature, yet if it be not so swiftly moved because of its heaviness, the percussion which follows is the weaker: Wherefore 'tis convenient in the first place, to reduce velocity to a certain measure.

Suppose then a Hammer A B, whose whole length is 6 feet, which is moved by a man to smite. I say, if it be moved equally with the same velocity which he hath in himself in the instant of percussion, and in the space of one second minute, shall make 4 circulations, that is 144 feet, (allowing the Periphery to be but 3 times the Diameter): If the same Hammer should fall according to the equality of the force of gravity, and accelaration of heavy bodies, it would not arrive to accomplish 144 feet in 5 second minutes, and it should fall from an altitude of 425 feet.

From whence 'tis concluded, that the altitude 425 feet is the measure of percussion made by the man, or the Hammer has so much velocity, while 'tis strongly smote, or impell'd, by the man, as the hammer would have had, if it had fallen singly from an altitude of 425 feet.

I have been willing to examine the calculation made by *Mersennus*, but could never find it answer experience, for we often use a *Pendulum* of 3 feet, one swinging, or stroke whereof is precisely equal to one second of a minute; and we have found in a *Semivibration*, or in the space of half a second, little more than 4 feet, to be past over by a body falling, *viz.* about 4 feet and $\frac{1}{2}$; but according to the proportion observed

ſerved by *Galileus*, it ſhould be 17 feet in one ſecond, wherefore in the ſecond ſecond it will be 51 feet, in the third ſecond it will fall 85, in the fourth 119, in the fifth 153, which being all added together, make 425, therefore the blow of the Hammer ſtruck by the man, is equal to that which is made by the ſame hammer falling 425 feet; in this ſuppoſition the ſpace which is paſt over by heavy things, deſcending, is reckon'd to proceed according to the ſeries of odd numbers.

But whatſoever the compariſon be of the *Impetus*, or force, produced from a man ſmiteing;and the *Impetus* produced by a weight falling; 'tis certain, that there is no *Impetus* produced from a man's ſmiteing, to which there cannot another be given equal to it from a body falling: But hithertoo the whole difficulty remains, *viz.* how we may meaſure the acquired *Impetus*, from a body falling from a determined height; let therefore a hammer weigh 1 pound, driving a nail at one blow (or percuſſion) one inch, whoſe force is equal to that which it would have if it fall from an altitude of 425 feet; and let it be demanded what weight being only laid upon the Nail, will force it in one inch, but that weight muſt be moved equal to the ſpace, to wit, it muſt alſo be moved one inch.

Many have been the opinions concerning this thing, for ſuppoſe a hammer of 1 pound, and 1 foot long, and let it be made after the manner of a Cylinder, ſome think, if there ſhould be a Cylinder made of the ſame thickneſs, *viz.* 1 foot; and 425 feet long, to wit, as much as is the altitude of the fall, which is equal to the percuſſion, and this Cylinder be put upon the Nail, it will force the nail into the board one inch, nevertheleſs, I ſee not on what foundation: for ſuppoſing the hammer to be half the length, and to have the ſame gravity; according to this conſideration, it requires a weight doubly greater, which is abſurd, therefore ſince this determination depends on the thickneſs of the hammer, which in this caſe hath no place, for neither will two hammers of divers figures, and the ſame gravity, have divers effects.

Others will have it, that a hammer of 100 pounds deſcending with one degree of velocity, will have the ſame force as a hammer of 1 pound, deſcending with a velocity as 100, which I eaſily grant: But hitherto I think nothing is effected, neither

neither is there had such a measure as we require, to wit, some weight to which percussion is equal, or a weight which is moved in the same manner as a nail, although it drive it one inch.

Mr. *Hobbs* reduces all percussion to the first endeavour which the weight hath, but knows not whether the first endeavour given be indivisible and determinate, and so in this explication he wraps himself in questions of continual division.

PROPOS. VI.

The measure of Percussion.

Suppose a hammer of 1 pound, and let it be of any figure, it matters not, which being struck with the force of a man, hath the same velocity, as if it had descended 425 feet, and drove a nail one inch, now 'tis demanded what weight this percussion is equal to: And 'tis certain, that a weight of one pound falling 425 feet, acquires a force to raise 1 pound 425 feet, which I shew in any Pendulum, wherein the weight ascends almost the same as it descends. Therefore this percussion seems to be in *equilibrio* with a weight of one pound, in moving through 425 feet: But if you ask what weight being moved one inch, will be in *equilibrio* with a weight of one pound, moved 425 feet, multiply 425 by 12, it makes 5100 inches in 425 feet; I say, if a weight of 5100 pounds be placed on the nail, the nail will be forced in one inch; for one pound moved 5100 inches, is in *equilibrio* with 5100 pounds moved one inch, wherefore the percussion of the man seems to be equal to 5100 pounds, which was to be shewn; nevertheless, there is a doubting in this calculation, because that the velocity of the weight ascending, always decreases, wherefore these things cannot be constituted, but according to the doctrine delivered of heavy bodies falling.

PROPOS. VII.

A Theorem.

The quantity being given of a stake, or nail, driven into any body by a determined weight, from a determined height, to find a weight which will perform the same from any other height.

Fig. 90. LEt the weight A be 100 pounds falling from 10 feet high, and driving the nail B one inch, a weight is required, which falling from 40 feet high, will perform the same effect; I say, it requires a weight of 50 pounds.

The Demonstration. The same effect is produced, if the quantity of motion be the same in both cases: But the quantity of motion is the same, for a heavy body falling from an altitude quadruple, or fourfold, hath double velocity of that which it had: But 100 pound movable with one degree of velocity, and 50 as movable by 2 degrees of velocity, have the same parts of motion: Therefore they seem to have the same effect; nevertheless, there remains a difficulty which is begat from the reflexion of bodies, which belongs to the velocity of heavy things descending.

PROPOS. VIII.

To make divers kinds of compound Engins.

BEsides the single kind of Engins before mentioned, to wit, the Ballance, the Leaver, the Wheel, the Pulley, the Wedge, the Screw, there may be made many other compound Engins, some of which we will describe, that so not only their great forces may appear, but also that any one may

perceive a ready way of making Engins for any occasion, and accommodate them to their use.

Mechanick Powers.

BOOK. VII.

Engin. I.

An Engin, whereby a Wagoner may raise his Wagon, or Cart, although loaded; also by it, the Roof of an House, yea, the whole Case of the House, may be raised.

Fig. 91. OF Iron, or other solid matter, make 3 wheels, the 2 lesser A and C, and the other greater B; the little wheel A hath five teeth, and the little wheel C the same; but the wheel B hath 20 teeth, and so is fourfold greater, and hath one common axis with the wheel C, also make of the same matter a firm Prisme D E with teeth, defend on every side all the case of wood with Iron, in which the teeth are included, the upper part being open, so that the teeth of the wheel A, lay hold of the teeth of the wheel B, and the teeth of the wheel C, lay hold of the teeth of the Prisme D E: But the axis of the wheel A stands out without the side of the case, and is turn'd by the handle G F H, and with the handle the little wheel A is turn'd, which turns the wheel B and C, and the teeth of the wheel C, running into the teeth of the Prisme D E, they move it upward, until the last tooth near E, be in the region of the wheel

wheel C; if now D on the top be made hollow, or E on the side of the Case sticking out, be put under the Waggon, or other weight, and the wheels being turn'd the Prisme ascends, and going forth of the Case, forces the weight upwards; and if the wheels are turned the contrary way, the weight descends likewise.

If to this Engin you add a leaver, one end whereof being put under the hollowing D or E, and the other end of the leaver lean, or stay on the Earth, and that part of the leaver, next the earth, be put under the Waggon, or other weight, and then turn the wheels, it will make a compound Engin much stronger, which you must note carefully, for indeed many Engins by addition of the like leaver are much helpt.

Engin. II.

To raise a vast weight with an Engin compounded of a Pulley, *Axis in* Peritrochio, *and a perpetual Screw.*

Fig. 92. MAke the Cylinder C D, in the middle whereof make 4 or 5 Spires of a Screw, which while the handle E F with the Cylinder is turn'd about, the Spires infold themselves with the teeth of the wheel B, and turn it about: And while the wheel B is turn'd roun'd, the rope B G H, drawn about the Pulleys G and H, is wound about its Axis: By this means, we may with great ease raise any great weight by the power F. I have caused the like Engin to be made, by whose means, I did move a Millstone with so little resistance, that with a small Silken Thred, fastned to the handle F, and pull'd by the hand, I have turn'd about the Screw, and taken it up, being the weight of 200 pounds, and not broke the thread. And if instead of the handle E F you fit a wheel furnisht with little boards, this being turn'd about with the breath of the mouth, will raise the Mill-stone.

Engin. III.

To take up a Milstone with an Engine wrought by the Smoak of a Lamp.

Fig. 93. THis Engine is admirable to the Beholders, to see it raise a weight of 150 pounds; it is altogether like the precedent, but that it hath a pair of toothed wheels between the Screw A, and the Pulleys, the first of them is immediately moved by the Screw, and the second is moved by the first, and about its Axis the Rope turns round; and that the Smoak of the Lamp may supply the force of the moving power, the centre of the wheel B C is firmly put into the Axis D of the Screw, whose Teeth running in each other, are turn'd round by the Teeth of the Wheels C and B, fixt to the Axis of the wheel F G, parallel to the Horizon; this wheel is so made of a thin Iron plate tinned over, that the whole plane of the Horizontal wheel consisting of the thin plate, is cut through with Channellings, and way for the Smoak to pass, in such manner, that while the Smoak of the supposed Lamp L, passes through by the oblique openings of the plate, it turns about the wheel hung to the Glassey cover H, upon the point of a Needle, and so poised, that it may turn round easily; and if one Lamp doth not suffice, 2 or 3, or more may be added: Also there may be more wheels than the foresaid two, and more little wheels of Pulleys. My Engine which performs the foresaid effect, consists of eight Wheels and Pulleys altogether.

Engin.

Engin.. IV.

By whose means a mighty weight is continually raised, although the Power be not continually applied, but now and then a little impulse presses it on by it its own endeavour.

Fig. 94. APply an Iron, or Stone Globe (or Ball) of a great magnitude and weight, to a spear of Iron, or Wood C D, and let the Globe be vibrated together with the Spear about the Poles A and B; moreover let there be some pretty little arm E F L, fixt somewhere about the middle of the little Axis, or Pin K, but movable without any resistance; join to this in F a crook F G turning easily in F, let the end E, of the little Arm, be made like the point of a Sword, or Knife, (or little tongue) which may touch the Spear, being perpendicular; then that part of the Spear which touches the little tongue, must be made sharp in the same form, and extended so, that the little tongues respect and touch each other.

Then the Globe being thrust with force, or being elevated, and falling again by its weight, mightily effects the Vibrations by going and coming back, and each part of the Spear made sharp in E, hitting against the little tongue of the arm, forces the pin F G towards G, which by that means, ever and anon, lays hold on new Teeth of the Wheel H, and turns round the Wheel, which cannot be turn'd back again, being hindred by the pin P, endeavouring the contrary. Another little Wheel being annext to the Axis of the wheel H, turns the Wheel I, about whose Axis the Rope of the Pulleys L M being turn'd, takes up the weight N, being fastned to the lowest Pulley; wherefore, if after the perpendicular stands still, and moves no longer, it be again raised from the centre and let down, its vibrations will effect in the same manner as before for some time, raising the weight in the mean while, although no power be applied, so that the weight seems to ascend of it self.

Note

Note, That you may add one or two wheels to the wheel I, that the weight may be taken up the easier, and less resist the motion of the perpendicular; moreover in stead of the Pulleys, you may use a Leaver, or a perpetual Leaver, with Axis in *Peritrochio, &c. Thirdly*, the longer the Spear is, and the heavier the Globe is, the longer the motion of the perpendicular endures. *Fourthly*, the upper part of the little Arm E, doth indeed endeavour downwards by its weight, but with so small endeavour, that 'tis easily moved by the Spear; the same end being but little inclined, so that a small part of the little tongue be touched by the edge of the Spear; and so also the wheel H ought to consist of small saw teeth, otherwise the force of the perpendicular will be too much allayed. *Fifthly*, 'Tis better, that only the upper part C F of the Spear be solid, and the remaining part F D be of a little chain flexible.

This Engin if it be ingeniously made, effects very well, and causes admiration in those that stand by: Besides, if the power be continually applied to the Spear, or to the perpendicular in D, which will move it of its own accord, a vast weight may be taken up with very little labour; and although the Globe D be very heavy, yet because it hangs freely, it is easily moved. In this case there is no need to make use of the little arm E F L, but 'tis sufficient that the Axis A B of the perpendicular be extended to Q, and there be fitted with a little iron hook, or catch, which may lay hold on the teeth of the wheel Q R; Or the little arm F G may be joyned to the Spear C D in E, and move the Pendulum with an opposite motion, to wit, from F towards G: But this wheel in this case ought to obtain another site than before, to wit, its plane ought to be parallel to the line of motion, which the perpendicular makes; and its teeth ought to be retain'd by the like pin, lest while 'tis free from the Clasp, or Hook Q, it return to the opposite part; likewise the whole Spear ought to be rigid, or hard. Yea, I confidently affirm, so that the spear which hath the proportion of a leaver be long enough, a vast weight may easily be taken up by one man, with only the wheel Q R, the rope being turn'd about the Axis S of the wheel, although no pulleys be added; for the leaver hath great force, although it be not in use in taking up weights, viz. because they know not the way whereby its motion may be continued; but we have found the precedent which is al-

together

together easie, and others of the like nature may be invented.

For let the leaver be A B C, whose prop is in B, and the power in A; by weighing down, or depressing this leaver, its other end C lays hold on the teeth of the wheel D E, and moves it, the iron Pin G hindering it to go back; and at the same time the rope E F being turn'd about the Axis of the wheel takes up the weight F; but the prop B ought to be furnisht with a ring above, in which the leaver must be put, lest it be easily moved to and fro, being only a little bent, that it may be transferred from one tooth to another below it.

Some things to be observed in the composition and use of Machines, or Engins. In the composition and use of the Engins aforesaid, and of others of the like nature, some things occur which deserve a peculiar observation.

First, 'Tis to be noted, that since in every Engin, that part which is next to the weight, feels a greater impression, or resistance of the said weight, and also ought to be more solid, firm, and strong: Example, In Axis in *Peritrochio*, or a toothed wheel and a screw, it will be convenient so to fit them together that the weight may be sustain'd immediately from the screw, and the wheels applied to the moving power; and the screw ought to be of more solid matter, and made more firm, since in toothed wheels they cannot be made so strong, as to sustain great weight.

This thing is of great moment, and therefore to be observed diligently in use, a screw, and also pulleys are wont to be applied immediately to a weight, for although a pulley seems to be less firm and strong to sustain a burden, because that the Axes of the wheels cannot be made so thick; notwithstanding each of them bears not the whole weight, even as neither any one rope that is drawn, but it is in a manner distributed to every one, so that from all, one as it were makes the resistance fit to overcome the weight.

Secondly, 'Tis to be observed, that some Engins may move a weight, or also take it up to some height, and yet notwithstanding of it self cannot move it to any further height; such are the wedge and the leaver, the first of them serving only for cleaving, but the second, if it be immediately applied to a weight, 'tis manifest that it can raise it but a little height: Wherefore as need requires, it behoves us to use divers kinds

of

of Engines; but if toothed wheels, or ſcrews, immediately ſuſtain a weight in the ſame manner that we have declared above, it acquires greater force, and will move the weight to a greater height; alſo if a weight be immediately faſtned to a ſcrew, it cannot raiſe it to a greater height than the length of the ſcrew: wherefore the ſcrew hath this conveniency, that 'tis firm and fit to ſuſtain a great weight, but cannot take up a weight very high: But on the contrary, the Pulley and Axis in *Peritrochio* can raiſe any weight to any height.

Thirdly, In any caſe which may be propoſed, reſpect muſt be had to the power, together with the weight which it ought to move, that an Engin be choſe which ſatisfies the intended end, for if the power abound, 'tis in vain to multiply, or augment the Engin, yea, with the loſs of much time: For as much as the more the Engin is compounded, the more time is beſtowed in the motion of the weight: On the contrary, it may happen, that ſuch an Engin may be choſe, by whoſe means the weight cannot be moved by the power propoſed, or not without a great deal of trouble. Wherefore according to the rule ſhewn before (to wit, the power muſt be increaſed in the ſame proportion, that the velocity of the motion of the power, hath to the velocity of the motion of the weight) Firſt, you muſt obſerve how much weight the power of it ſelf can raiſe, or move, without an Engin, then from the known weight which is propoſed to be moved, it will be eaſie to determine what kind of Engin is required; where note, reſpect muſt be had to the proportion of the weight of the Engin, and chiefly to the reſiſtance of it, which ariſes from its parts, rubbing, or wearing, againſt each other, for there are ſome Engins which make ſmall reſiſtance to the power, as Axis in *Peritrochio*, where there is no other rubbing or wearing, but in its two Poles; alſo the leaver makes no reſiſtance by rubbing; but the ſcrew becauſe of its many ſpires reſiſts much, and eſpecially if the ſpires be not very ſmooth, and the convex, and the concave do not exactly anſwer each other; in like manner the Pulley, the more wheels it conſiſts of, the more motion it reſiſts, becauſe of the multiplicity of Axes, which rub, or wear the Poles.

Fourthly, Obſerve in any Engin, the Wedge excepted, (of which by and by) another Engin may be joyned to encreaſe its

its force, ſo to the leaver we may apply Axis in *Peritrochio*, likewiſe we may add the ſame to the Pulley. Laſtly, We increaſe the force of the leaver, by adding the Screw: Alſo the head of the leaver may be elevated by the Wedge, yea, 'tis oft-times uſeful to lay under the leaver a firm and ſolid body, then between it and the head of the leaver, the Wedge is thruſt and drove in.

Fig. 95. Pulleys are not wont to be immediately applied to the leaver, for although the rope A D of the Pulleys may be faſtned to the leaver C E in D, and by depreſſing the head of the leaver E may draw downward, notwithſtanding, becauſe this motion cannot be continued any further, therefore inſtead of the leaver, Axis in *Peritrochio* is wont to be uſed, which hath the proportion of the perpetual leaver, as is ſaid above, for the ſame reaſon the Screw is not added to Pulleys; for although this may draw the rope a little more, yet the weight is thereby only but little raiſed; wherefore this artifice may be uſeful in caſe the weight were to be raiſed but little from the earth; laſtly, the Wedge can in no wiſe help the Pulley being immediately applied.

The leaver may beneficially be added to the Screw, yea, without the Leaver, the Screw is not wont to move, as is obſerved before, it may alſo uſefully be added to Axis in *Peritrochio*. Alſo the Screw may be helpt by Pulleys, but they are ſeldom uſed, and the motion is but ſmall, as appears by conſideration. But no manner of force is acquired from the Wedge, ſince it is not applicable to it.

The Wedge only ſeems not to acquire force by means of other Engins, for 'tis not moved by the force of any Pulleys, or Cranes, as other Engins are, but only by percuſſion: Wherefore that the Wedge may acquire greater force, it behoves to find a proportion, whereby a greater percuſſion appears; and this alſo may better be done by other Engins, to wit, if ſome great Iron weight made in the faſhion of ſome Hammer, be lifted up by the Engin, and then falling by its weight on the Wedge, it forces it in; but eſpecially by the Leaver A B, whoſe Prop is C; if to the end A, *Fig.*96. there be fitted a great Iron Hammer, or Beetle, which being elevated by the turning of the wheel G from F towards E, for if the wheel be fitted with Pins, while theſe are born down, they hit againſt the end of the leaver B, and together with

that depressing, they take up the hammer A, which by its weight falling again drives the Wedge D: And the wheel G may be moved by a multiplied proportion, or by other wheels annext to the same, or by a capstand, or any other way: Commonly in Smiths Workshops 'tis moved by the force of water falling on the little boards of another greater wheel, fixt to the same Axis.

Hence it appears, by what artifice Engins are to be coupled, or join'd together, and what is to be observed in their combination, or complication, according as there is need of greater, or lesser motion, for the raising of heavier, or lighter weights.

Engin V.

Fig. 97. THE Capstands, or Windlaces, which obtains a vertical site are of great use, because that they may be moved only by Animals, or Cattel, which alone properly and vigorously move with an Horizontal motion; nevertheless, it hath this inconveniency, that one weight being raised up, the Engin ought to be turn'd about with a contrary motion, and so much time will be lost, while the Horse is fitted for the opposite part; therefore, to shun this inconveniency, let the Engin be composed of two windlaces A B, C D; to the Horizontal one of them, fasten ropes with two Buckets (as for example) to draw water, or raise another weight, so that while one Vessel ascends full, the other may descend, you must fit to the Axis of the same windlace, two toothed wheels, or tympanes G and H, beneath the toothed wheels, let there be another windlace C D, furnisht with another Tympane, or Horizontal wheel G H, which suppose to lay hold on the wheel G, while the weight E is raised, and the empty vessel F descends; then the weight E being raised, move forward a little the tympanes, or wheels G and H, towards B, that the tympane, or wheel G, may forsake the teeth of the wheel, and these may be implanted to the other tympane, or wheel H, which may easily be done several ways; for so the windlace A B will be turned on the opposite part, and

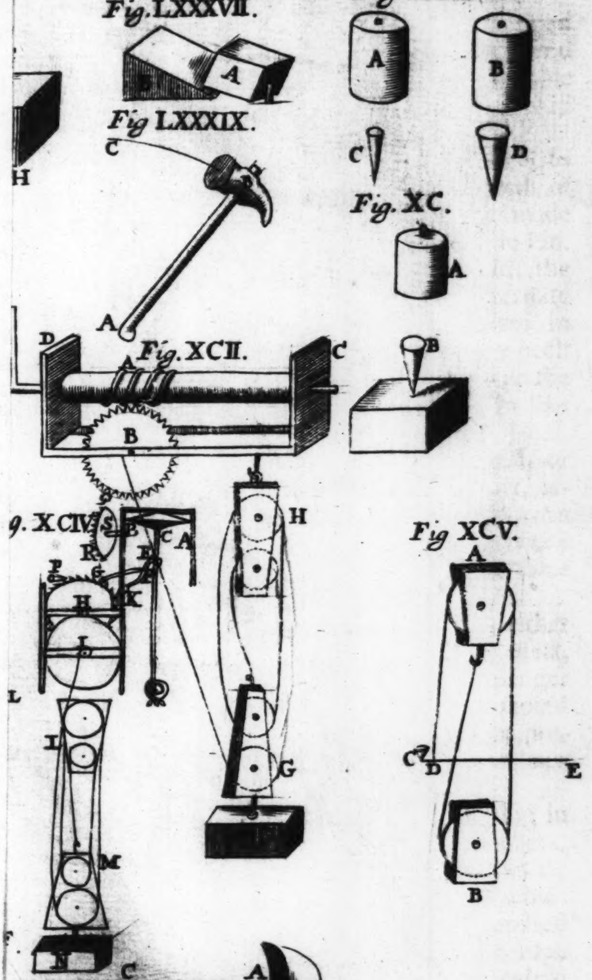


Fig. LXXXVII.

Fig. LXXXVIII.

Fig LXXXIX.

Fig. XC.

Fig. XCII.

g. XCIV.

Fig XCV.

Fig. LXXXV.

Fig. LXXXVI.

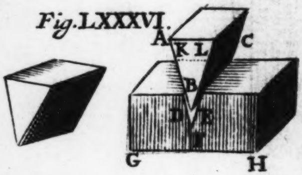


Fig. XCI.

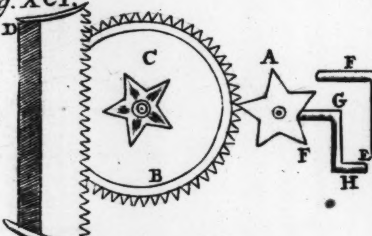


Fig. XCIII.

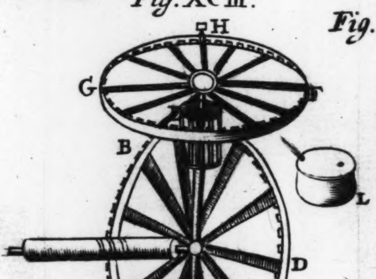


Fig. XCIV.

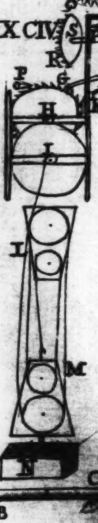
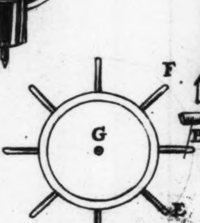


Fig. XCVI.



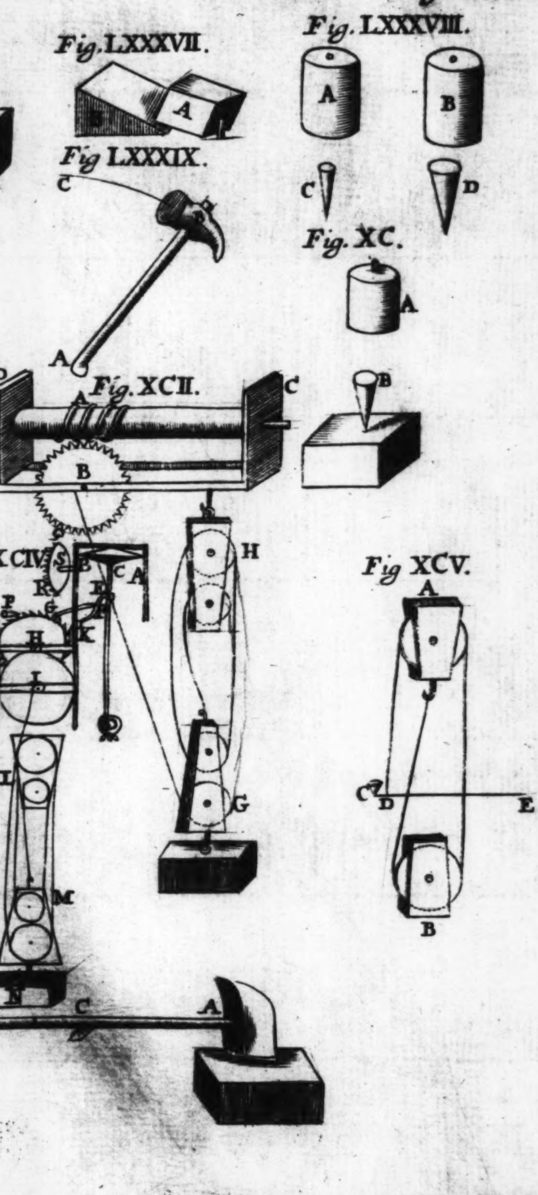


Fig. LXXXVII.
A
Fig. LXXXVIII.
A
B
C
D
Fig LXXXIX.
C
A
Fig. XC.
A
Fig. XCII.
A
B
C
B
XCIV.
S
B
C
A
R
E
P
G
H
K
L
M
N
C
A
H
G
Fig XCV.
A
C
D
E
B

and while the weight F aſcends, the veſſel E, being emptied in the mean time, will deſcend, and they will always aſcend and deſcend alternately, or by turns; alſo if the power (ſuppoſe a horſe) be applied to the end I, of the leaver I L, it will turn about to the ſame part continually.

Or the tympanes, or wheels G H, may eaſily be fitted, ſo that always either may be ingrafted to the oppoſite teeth of the ſame wheel C; but nevertheleſs, they muſt be made movable about the Axis A B, yet ſo, that by means of the Pin, or the ſmall leaver, N and M may eaſily be joined with the Axis, or Windlace, as often as you pleaſe, for ſo by alternate force one tympane or wheel, which ſhall be firſt made firm in the Axis, by help of the leaver, reſiſting the moving wheels will move the windlace, and take up the weight, while the other free from the pin, will obey the moving wheels in like manner, as if it were not.

But if you would apply men to the vertical capſtand, or windlace, ſince theſe are eaſily fitted to the contrary part, after the weight is raiſed, yea, they may commodiouſly turn about, leſt they ſhould be giddy with the motion always one way, you may fit a double veſſel to draw water in the ſame manner, as appears in *Fig.* 98.

Moreover a windlace in a vertical ſite, if it be fitted either of the foreſaid ways, it will much better perform the effect, than a wheel, or a crane, which many uſe not without danger of their lives, for if a rope, as it ſometimes happens, ſhould break, thoſe which turn the wheel, from the great force preconceived, are thrown out of the wheel, which cannot happen in a vertical windlace.

This ſame windlace, or capſtand, Seamen uſe, to bring in great weights into their Ships, alſo to draw up their Anchors; in which Engin this is to be noted, that becauſe the Cables are ſo thick, that if they were many times wound about the windlace, or cylinder A B, in *Fig.* 99. the Engin would be rendred uſeleſs; therefore they only receive 3 or 4 Spires of the rope about the cylinder, ſo that while one end of it C, is turn'd about the windlace, the other end D is thrown away; and that the rope ſhould always conſiſt in the middle of the cylinder, the cylinder muſt be made in the manner of a Cone, broad, or thick in the bottom, as you ſee in the figure; and by this means the rope will always be kept in the middle.

Engin. VI.

To remove a Mountain, or heap of earth, from one place to another easily and quickly.

Fig. 100. LET the Mountain, or Hill, or heap of Stones be A, to be removed to the place B; to save time in going and returning from one place to the other, as also, that the motion whereby the Earth, or Stones, is transferred from A to B may be swift, we may make use of the following industry: Erect at the foot of the Mountain, or in its middle, a great and solid wooden column, or piece of timber C D, and erect such another in B, *viz.* E F, affix at top of each piece, or column, the wheels D and F, and make hollow each wheel in the circumference; and put about them a great strong rope, extended parallel to the Horizon: But if the distance from A to B be great, least the rope should be too much stretcht or bent, raise other such like pieces, or columns in the middle, with their wheels made hollow as aforesaid, to sustain the rope parallel to the Horizon; on the rope thus doubled, here and there hang baskets, which must be so far distant from each other, that they hinder not one another; and the ends of the pieces must be so placed, that the power applied to the leavers G and H, may be turn'd about their Centres; for so the whole Rope with the Baskets hanging on it, will be turn'd about successively: Wherefore, if men keep filling the baskets in A, and others unload them in B, the whole hill will be easily transferred from A to B.

Where Note, That the greater the wheels D and F are, the swifter the rope and baskets will be turned about: Which motion about the axis, or piece of timber being easie, may be accomplisht by means of short leavers, that so the motion of the baskets may be greater than the motion of the power about the piece of the timber. Besides the saving of labour, and the gaining of time, which is effected by this Engin, it hath likewise this conveniency, that if between the two places A and B, there should be a river, or stream, or such like inaccessible,

accessible, as if the Earth were to be transferred from a Mound, or Hill, to the next adjoining Fields, and there were a large deep Mote, or Ditch, between them, you could scarcely obtain your desire any other way.

Engin. VII.

To draw Water, or Mineral matters, out of deep Wells, or Pits.

Fig. 101. GEorge *Agricola* describes five divers Engins, invented and used to this end, in his 6th book of Minerals; the first 3 whereof are wrought by men, the other two are turn'd about by horses, in all of them he uses a double Bucket, or Basket, one of which being empty descends, while the other being full is raised up; in these Engins, if the Pits be deep there is this inconveniency, that when the double rope is of such length, as the depth of the Well, it is necessary that it be turn'd about every where on the Axis of the wheel, and it will take up much space on the Axis, and require the Axis to be the longer; and by how much thicker the rope is, the Axis requires to be the smaller; whence it will happen, if the Well be not broader than the whole space of the Axis, on which the rope winds about, the Buckets, or Baskets, will hit against the sides of the Well, and retard the motion; but if you make the Axis thicker, there will be fewer circumvolutions of the rope, and it will occupy a lesser part of the Axis, but then it will require a greater force of the power to raise the weight, or wheels much greater, to which the immediate power is applied; moreover, that which makes to the present thing, and is of greater moment, is, that the motion whereby the weights ascend, is for the most part very slow; wherefore we will describe this Engin, by whose help the weight is raised with a motion doubly swifter than the motion of the power. For let there be a wooden Cylinder A B, erected perpendicularly, turning easily on its poles,

poles, on whose head sit a little wheel A equipped with small cylindrical staves, being a kind of cog wheel, but in the middle let it be fitted with a leaver, or a double one C C, to which the power is to be applied: And we will suppose the power any way applied in C, the circumvolution of this Cylinder to move circularly through the circumference of six feet, so that four turnings round finishes 24 feet; and in the same time by means of the little wheel A, the wheel D E too finishes a circuit by only one turn; but the wheel F G is turned six turns, or times, and then the Axis H I is moved quadruple of the wheel G, to wit, it makes 24 turns, or circumvolutions: Wherefore, if the Cylinder I H (on which the rope whereon the baskets are fastned winds about) be of such a thickness, that in its going round, or periphery, 'tis equal to 2 feet, the basket will ascend 48 feet, *viz.* by a motion doubly swifter than the motion of the power applied in C.

Perhaps some may say, that so many multiplications of wheels is not necessary, if so be the same proportion, whereby the velocity of the motion of the weight increases, or of the baskets, above the velocity of the motion of the power, a greater power also ought to be applied: Wherefore, when the velocity of the weight, is greater than the velocity of the power, it may be obtained by means of one wheel only, all the rest are used in vain.

I answer, that is true indeed, in speaking Mathematically; but Physically, and in Practice the thing is other-
Fig. 102. wise, which may be seen at the first view; for if the power be applied immediately to the Radius's A, B, so that it move the Cylinder C D, with a motion doubly greater than the motion of those radius's, or of the power it self, the power is more tired; but less, if the other wheels aforesaid come between, or being disposed in any other like manner, so that the circle which the power describes by its motion be greater: The reason whereof may be twofold, the first is, because when in this circular motion, the power being applied to the radius, the radius hath the proportion of a perpetual leaver, and the leaver as is said before, is changed in each point of the Circle, also the motion of the line of direction, (that is to say, according to which the power impresses the force to the leaver) ought continually

to change, since it ought always to be perpendicular to the leaver; and 'tis manifest, that a power cannot exactly every moment change the direction of its force, so that any force shall be according to a tangent line of its circle, for as much as force recovers by turns, so *Impetus* impresses often times by turns, that therefore the whole *Impetus* cannot be guided to divers lines; therefore since necessarily this imperfection of *Impetus*, subsists in every animated power (of which only we are here speaking) then the motion will be the easier, where the power sustains least of this imperfection: But this imperfection is lesser, if the motion of the power be circular, or the motion of the circle be greater; if so be in a greater circle, the deflexion from a perpendicular line, or tangent, be always lesser, surely in going about, we move more easily by a greater circle, than by a less, as appears manifestly in the practice of horses going about, for as much as while they continually bend, and endeavour to make a new line of motion, they are much tired.

The second reason is because as appears in the said Engin, *Fig.* 101. the motion of the parts of the Engin decreases, even to the wheel F, which is again moved more swift by the wheels E and D, and also effects a swifter motion in the Axis I H, and in the weight bound to the rope: For from this decrease of swiftness, even to a certain limit of the Engin, and again from a new increase, even to the end of the same Engin, and to the weight it self, it comes to pass, that the power suffers the less resistance: I say, the successive compression of the parts of the Engin, or the endeavour of the *Impetus* is propagated from the power towards the weight; and since the motion is more slow about the middle of this Engin, than in its other parts, there, after a certain manner, is the resistance of the weight gathered together, that therefore the power may suffer the less from this chiefly, because the direction of *Impetus* from the power towards the weight often-times coming unlookt for from new *Impetus's*, necessarily prosecutes its Journey towards the weight, nor cannot reflect it towards the Power.

Engin

Fig. 101. Engin. VIII.

To apply a wheel to the precedent Engin, and to others of the like kind, by means whereof the power is eased.

BEcause the Engin last described, and all others of the like nature, for the most part require the power to be sufficiently strong, in as much as it ought to produce in the movable, a swifter motion than the motion which moves it; therefore no Industry must be ommitted, whereby the power may by some means or other be helpt, or less tyred. And that will best be done by adding a wheel of some heavy matter, and altogether solid to the Engin, as if to the Axis A B of the precedent Engin, there be fastned an immovable wheel made of Stone, L N, parallel to the Horizon: For although at first sight it seems rather be be an impediment, nevertheless, it appears by experience to add much to the acceleration of the motion, with less tyring of the power; for if it be exactly in *Equilibrio*, so that the Axis pass precisely through the Centre of gravity of the Stone Wheel, it will resist its circular motion little or nothing, as from what is said may be easily gathered, and as it clearly appears from what hath been said of circular motion; but from another original, whence once it hath conceived an *Impetus*, it retains it long in it self, and the more, by how much the heavier it is, so that for some space of time it will move other wheels and the weight, by only that *Impetus* conceived at first, without any new impression from the Power; whence it happens, that although the power cease for a little time from impressing a new *Impetus*, or at least doth not exert its force always uniformly, or produces an unequal *Impetus*; nevertheless the *Impetus* conceived by that wheel, ceases not to propigate further, and reduces that inequality, or deformity, to some kind of uniformity and equality, which how much 'tis in the present affair may easily be collected from what hath been said before.

But now observe, this kind of wheel may be fitted to the Engin

Engin in divers parts, and sundry ways; and first, as to that which pertains to divers parts; 'tis manifest in the Engin now described, that it may be applied either to the Axis or Cylinder A B, or to the Axis E N of the second wheel, or to the Axis F G (in which case it will have another site, or position, *viz.* perpendicular to the Horizon, or vertical) or lastly, it may be placed allso to the Axis H I: Wherefore 'tis questionable what place it ought to be fixt, to perform the best effect. I say, then it will perform the best effect, if it be placed there were the greater force of *Impetus* is gathered together, to wit, in that part of the Engin, which ought to move most swift; for since it better obtains its end by conceiving a greater *Impetus*, and since by reason of more gravity, 'tis capable of more *Impetus*, 'tis plain that it must be placed there, where the greatest *Impetus* is conceived: From hence it is that in the Engin described above, 'tis better placed in the Axis I H, than in the Axis GF, because that is moved swiftest: And better in the Axis G F, than in the Axis A B, because while the Axis G F, is turn'd round six times, the Axis A B is turned only 4 times; Lastly, 'tis better placed in the Axis A B, than in the Axis E N, since this is turned slowest of all. But when 'tis placed in Engins, whose parts the further they are from the power, are moved slower and slower as some are, this wheel will be more conveniently placed to the first part of the Engin, to which the power is immediately applied. But contrariwise in those Engins in which the motion is swifter, the more the parts are distant from the Power, the wheel must be fitted to hindmost parts, agreeing with the more remote parts from the power.

Also observe, wheresoever the foresaid wheel is placed, it ought to be the more heavy, by how much slower it ought to move; but if it be placed where it moves swiftly, a less proportion of weight will serve: For as much as it appears from the doctrine of circular motion, that the heaviest wheels maintain the imprest *Impetus* longest, although they are moved slower than the wheels that are lighter, which lighter wheels, if an equal *Impetus* be imprest they move swifter, but sooner part with or loose the *Impetus*.

Moreover, I observe, and I propose it as a new invention in this matter of great moment, that 'tis possible by means of this wheel, to promote the celerity of the motion much in

the movable, or thing moved, but adds but little to the power.

Fig. 103. For let the Power be applied in H, which moves the Axis A B, and by that means the wheel B C, the wheel D, and at last by the help of this, the little wheel E, with the axis E I, to which the rope is fastned, and turn'd about, that takes up the weight, or for any other use. In this Engin you see the motion always accelerated from the power towards the weight, or the Extream part of the Engin E I: If therefore there be ingrafted to the Axis E I, a wheel of an indifferent weight, but yet large as F G, this from what hath been said will notably promote the Celerity of the motion, so that the same power may be effect a swifter motion, using only the same power with this wheel than without it: Now therefore, since the *Impetus* once conceived, may easily be continued by this wheel, some power being added immediately to it, which either continually, or at least now and then, and often will renew that conceived *Impetus*: Example, a rivulet of water falling from on high, on the little boards, or rather bucket of this wheel, it will come to pass, that how little soever this impulse be, while 'tis in a manner continual, or at least often, notwithstanding being added to the impulse already conceived from the great wheel to this wheel, and so also to the movable, it effects the Celerity.

Secondly, The foresaid wheel may be placed either in a perpendicular axis, so that it may obtain an Horizontal site, as is seen in the foregoing Figure, or in an Horizontal axis, so that it may obtain a vertical site or perpendicular to the Horizon, as in the present Figure: And although in order to motion, the facility differs little, which way of the two you place it; notwithstanding, I esteem it more necessary to be placed in a vertical site, because, when in this case, the axis to which 'tis applied necessarily ought to be Horizontal, the weight it self of the wheel lies on two Poles, and so being divided between two, each Pole suffers less compression, and the resistance is less which arises from the wearing, or rubbing of the same Poles: But if it be placed on a perpendicular axis, the whole weight of the wheel lies on one Pole, *viz.* the lowest, it may seem to retard the motion of the other wheels: Nevertheless, because that very often the motion of the axis is wont to be made in a perpendicular site, bearing on the

middle

middle part of the lower Pole, they ſharpen it ſo, that the whole weight is born on a ſmall part of the Cavity, that, as I have ſaid, therefore, the wheel may move the others with more eaſe.

Laſtly, The ſame wheel, of which we are ſpeaking, may be uſed doubly in a vertical ſite: Firſt, ſo that it ſtand wholly hang'd up in the air, and equilibriated, as in the preceeding Engin. Secondly, So that it inſiſt or ſtand on the ſubjected pavement, and turn'd about upon it; in which caſe it hath alſo more force, than if it were ſuſpended wholly in ſome axis: But the Pavement ought to be made level and plain, and ſolid, as of poliſht marble, or ſuch like matter, and the circumference of the wheel, which immediately touches the pavement, ought to be exactly turned, that no impediment retard the motion. So the wheel A B being applied to the extream part of the leaver C D, to which leaver in like manner, apply a power moving the Cylinder, or Axis D E, and by this means, the wheel E, and oftentimes other wheels, for while the Cylinder is turned about by the Leaver, the Wheel A B, roles about its Leaver, leaning on the pavement, and from a double motion, to wit, one about its centre, or about the Leaver C D, which is inſtead of an Axis, and the other about the Cylinder D E, while it runs out from B to F, *&c.* And in this manner, it may be applied almoſt to all Engins, but eſpecially, to thoſe with which we uſe to move great weights. And the greater this Wheel is, the better it performs the effect, ſo that the weight be in propoɾtion to the power applied. *Fig.* 104.

Engin. IX.

To raise the Water of a Fountain always flowing, to any height, by a voluntary motion, although the height be greater than that to which the Water descends.

Fig. 105. THis Invention, if you entertain the perpetual motion, easily secures to it self the chiefest place: For 'tis easie to draw Water by a voluntary motion, to a greater height than is that from whence the Water of the same fountain descends, as is manifest in Spirital Engins, but to give it a continual motion, that it shall never require the hand of a man, this without doubt deserves great praise.

This Engin contains two buckets, filling them from the fountain, of which while one ascends the other descends continually, without any labour, and serves the Water for Domestick use; therefore to make the Water ascend to a space doubly greater, than is the space of the Water descending, it must be disposed in this manner, as is represented in the Scheme.

A, Is a Vessel, or lesser Bucket which ascendeth, this being full, weighs less than the Bucket M being full, which descends; but being empty that weighs more than this when empty; Hence 'tis, that while both are filled together from the vessel S, the Bucket M descends, and by its weight draws the Bucket A up: But on the contrary, while both together are emptied, the Bucket A descends, and by its weight draws up the Bucket M.

B, Flaps to keep the Water in, tyed with a string to the leaver D, this leaver D turning easily about the Axis C crosswise, while the Bucket is raised up on high, hits against the piece of timber Z Z, and opens the flap B, and gives way for the Water to pass through the little Pipe E into the Vessel X. The said flap B being somewhat large, whereby the bucket may be emptied the sooner; make the bottom somewhat hol-

low.

low, lest the emptying of the Bucket any way hinder; and anoint it with grease, that the Water may keep in the better.

C, A stick joined to the bucket a-cross, and made fast to the leaver D, which we call an axis a little before, because of its form.

D, A Leaver with a little Wheel, or a Pulley *d*, annext to its top, the lower end of which leaver, is bound to the flap B, with a string, for this end, that while the Bucket A, ascends towards the piece Z, and hits against the Leaver, the flap is opened and the Water goes forth.

E, A little Pipe, or small Tube, joined in the bottom of the Bucket, so that it answers beneath the mouth of the hole of the flap, through it the Bucket is emptied within the vessel X, the Orifice, or Mouth, and its cavity, are not less than the hole of the flap B.

F, Rings on both sides of the Bucket, in which are ingrafted Iron threds, or chords G G.

G, Iron threds, or chords, which must be firmly extended, lest the Bucket in going and coming hit against the side, and especially while the leaver *b* hits against the piece Z.

H, A round piece of Timber, to which the said Iron Strings or Wyers are fastned, which Threds or Wyers ought to descend from the piece Z, even to the piece H altogether perpendicular, and to be distant from each other such a space, that they strain not the Rings that are fixt to the Buckets, or at least but lightly, that so the Bucket may ascend and descend freely, and without violent wearing.

I, A Rope to which the Bucket A is fastned, passing over the little wheel, or pulley K, and within the pulley L, and from thence extending to the fastned pulley K *e*, to whose top it is fastned.

K, A Pulley joined to the piece Z, which must be large for many reasons, and a hole in the middle, and let there be a small Axis passing through the hole, which will bear the weight of the Bucket and Water.

K e, A fixt Pulley, that is, it doth not turn about its Axis, but is immovable, or rather a fourth part of a Pulley, its Semidiameter ought to be equal to the Semidiameter of the Pulley K, that therefore the motion of the Bucket M, may remain uniform, that is, that it may remain always in the same perpendicular; otherwise the Rope of the Bucket M, will raze against the Iron threds, or chords G G, and so the motion will be hindred.

L, Ano-

L, Another Pulley, which while the rope I draws on both ſides, cauſes the aſcent of the Bucket A, to be as ſwift again as the deſcent of the Bucket M, and therefore that runs double the ſpace in the ſame time as this; for which cauſe the weight of the Bucket M full of Water, ought to be as much more as the weight of the Bucket A being full; but on the contrary, the Bucket A, although it be leſſer than the Bucket M, ought to weigh more than it, they both being empty, notwithſtanding the exceſs ought to be indifferent, and ſo exact, as will ſuffice that the Bucket A being empty in deſcending, may draw up the Bucket M being empty.

M, A Veſſel, or a great Bucket, which by its deſcent draws up another leſſer A, it hath a flap B, and little pipe E in the bottom, rings F F on the ſides, Iron threds or chords G G, as the former Bucket A, nevertheleſs, the leaver is applied in a divers manner.

N n, A leaver placed upon the Bucket M a-croſs, to whoſe end *n* there is annext a ſtick *n a*, hanging or dangling, this, while its end *a*, deſcending with a bucket touches the Earth, raiſes the leaver N *n*, and opens the flap B, of the bucket M, at the ſame time in which the flap B, of the bucket A is opened.

O o, Two ropes faſtned above to the bucket M, and below to the piece Y, or to the Earth, to the end, that M ſhould not aſcend beyond its due limits, nor A deſcend beyond his: 1, 2, 3, 4, *&c.* are leaden weights to weaken the *Impetus* of the motion in the deſcent, while they lye ſucceſſively one after another on the earth, and leſſen the weight of the bucket to which they are faſtned; but in aſcending while they are elevated from the earth one after another, they adjoin new weight to the ſame bucket; and they may be more or leſs, according as is neceſſary.

P, A piece laid athwart a little above the bucket M, having a hole in the middle, through which a rope paſſes freely without rubbing, to which the bucket is faſtned even to the knot Q, which knot when it comes to the piece P, ſtays the motion of the bucket M, and hinders it, that in deſcending it daſh not againſt the earth, nor the bucket A in aſcending hit againſt the piece Z Z.

Q, The knot ſpoke of but now, to it may be tyed a ſtaff a-croſs, or overthwart, which may eaſily be looſt and changed as need is.

R, Ano-

R, Another knot with a ſtaff athwart, which muſt be ſo far diſtant from the former knot, as is the ſpace of deſcent of the bucket M almoſt to the earth; this knot may execute the office of the ropes O *o*, if the weights 1, 2, 3, *&c.* be not neceſſary.

S, A veſſel deſigned to receive the Water from the Fountain, it hath a flap, and a little pipe in the bottom, as have the buckets A and M, nevertheleſs, the little pipe ought to caſt out the water from each ſide, and at the ſame time almoſt, to fill together the bucket A, and the bucket M; and becauſe theſe buckets are of divers capacities, the ſaid two little pipes ought to caſt out an unequal quantity of water from the veſſel S: This veſſel muſt not be in the middle between the two buckets, but behind after them.

T, A leaver faſtned by a ſtring or rope, to the flap of the Veſſel S to open it; on the top it hath the table *f* adjoined, that the ſtaff V may hit ſecurely on it, and raiſe the leaver.

V, A ſtaff fixed firmly to the ſide of the bucket M, with a little wheel or pulley on the top; this when its pulley raiſes the leaver T, and opens the flap of the veſſel S, while the buckets are filling, the bucket M deſcends, and with it the ſtaff V, and ſo the leaver T is let down, and the flap of the veſſel S, is ſhut again, until the veſſels are emptied below, and above; M returns back with its arm V, and raiſes the leaver T again, and opens the flap of the veſſel S, as before.

X, A veſſel to receive the water of the bucket A: This veſſel ought to be ſuch a ſpace beneath the piece Z, that while the leaver D hits on the piece, the little pipe E within the veſſel unloads the water of the bucket A.

Y, A piece of timber, a ſtump, or a ſtone, to which the ropes O O are faſtned.

Z, A piece of timber to which the pulleys K and K *e* are affixt; this piece of timber hath the table *b* affixt to it at right angles, on which hits the little wheel of the leaver D, and draws near to the wall, and draws the bucket A with it towards the wall, that the little pipe E may hang over the head of the veſſel X; which may alſo be done otherwiſe.

This Engin which was made at *Rome* in the Convent of St. *Mariæ de Victoria*, the leſſer bucket did contain more than an whole Urn of Water (at *Rome* they ſay *un Barile*) but before while they uſed leſſer buckets, the Engin wanted ſucceſs.

Note

Note also, that the bucket A ought first to be emptied, and then the bucket M, otherwise the water as yet contain'd, by the more heavy weight, would descend with too much force, but you may obtain that by making the little pipe E of a due magnitude.

Its flaps are of matter, and form, and magnitude, that the water before they are opened, no way runs out; in the foresaid *Roman* Engin, a palm, or hands breadth was the length, and half a palm the breadth: The matter was Lead both of the little tongue, and the table, in which the hole was, and was shut by the tongue: If they are made of wood, they have not so good success.

The Pulley L hath as much diameter, as is the distance between the true Pulley K, and the fained one K*e*.

The weights 1, 2, 3, 4, *&c.* are fastned to the ropes O O, for this end, to stop the *Impetus* of the descending bucket A; for besides the *Impetus* which always increases in heavy bodies descending, the *Impetus* likewise is too much acquired from this, that when it comes to the piece Z, the whole weight of the rope I hangs on the other part of the Pulley K, and increases the weight of the bucket M; but when after the emptying of the buckets, the bucket A being heavier than the bucket M, together with the weight of the rope, it begins to descend, and draws with it the rope I, and therefore draws to it the weight of the Rope, and takes away the same from the bucket M. Then how much more is added to one, and taken from t'other, so much the more the *Impetus* increases of the bucket A; which *Impetus* is weakned by the foresaid leaden Plummets, while they are raised from the earth successively.

Also beware, lest the ropes are made wet by rain, or by water, otherwise they will be contracted, and not retain their due length.

Lastly, 'Tis observed in the foresaid Engin that the water is raised as high again in the bucktet A, as it descends in the bucket M, by reason of the Pulley M, which doubles the rope: But if any one would have the water rise four times as high, he must add another Pulley, and another rope; in like manner by the help of three pulleys he may make the water ascend to eight times the height, *&c.* so that the water contain'd in the bucket M, be quadruple or octuple, of that which

Fig. XCVII.

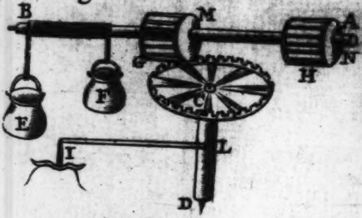


Fig. X

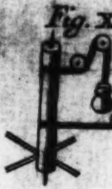


Fig. C.

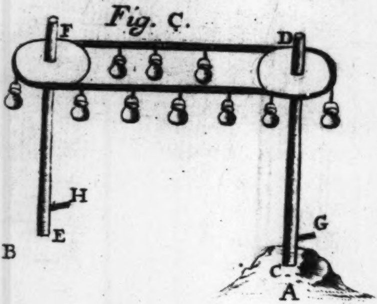


Fig. CIII.

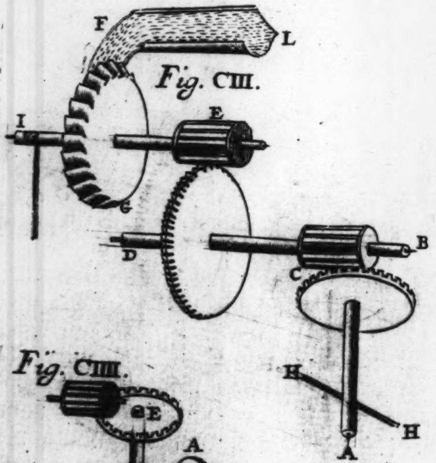


Fig. CIIII.

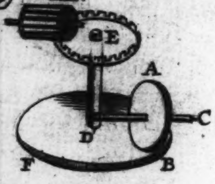


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Fig. XCVIII.

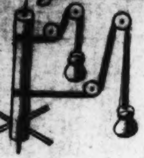


Fig. XCIX.

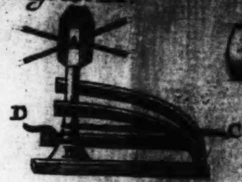


Fig. CII.

Fig. CI.

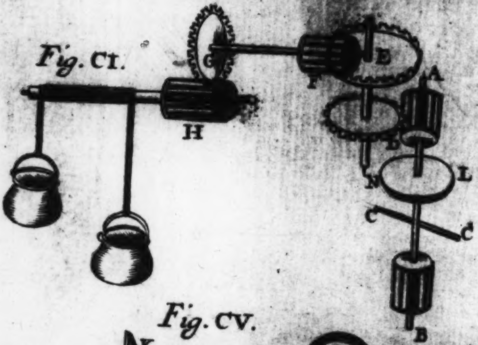
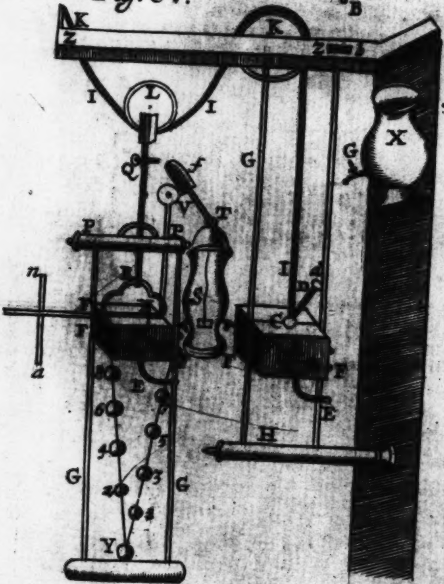


Fig. CV.



is in the bucket A, yea, and ſomewhat more, that the bucket being full, may out-weigh the bucket A, and may draw it downwards; although the bucket A being empty, ought always to be heavier than the bucket M in like manner being empty.

Schottus in his *Technica curioſa* deſcribes an Engin ſomewhat different from this, which was made at a Noble Man's Houſe at *Baſil* with good ſucceſs.

Engin. X.

To perform the ſame thing eaſily in any given proportion of Height.

Fig. 106. LEt there be a fountain of conſtant Water running into the Veſſel A, or at leaſt let it be derived thither from ſome continual Fountain, and you would raiſe it to the Veſſel B, whoſe height above A is 20 feet, but from A the water cannot deſcend deeper than to C, to wit, 10 feet beneath the Fountain A; nigh the Veſſel B diſpoſe the Axis D E in an Horizontal ſite, eaſily turning about the extream poles; diſpoſe ſuch another like Axis near the Fountain A, and annex to each of them the Tympane F, and the wheel G I; Tympanes of this kind are divided by Iron Rods, or Sticks, and of ſuch a largeneſs, that there may be put upon them conveniently little Veſſels, joined together by a Chain annext to one another in manner of a Ring; it matters not what faſhion the little Veſſels are of, ſo that they receive the Water eaſily into them, and empty the ſame out of them again, we have delineated two of them together in the figure L N; thoſe which are put about the upper Tympane hang on the ſame, and they extend or reach along to the water of the fountain A, and are dipt into it ſucceſſively, and draw the ſame while the Tympane is turn'd about; but when they come to the top of the wheel, they unload the ſame water, and pour it into the upper Veſſel B. But from the water of the ſame fountain A, the Veſſels put about the lower Tympane muſt firſt be fill'd, which ought to have a little hole open in the bottom, that the water may flow

from the Vessel L into the lower Vessel N, and from N into another, and so successively all the Vessels of one side are fill'd; for then the weight of them and the water turn about the Tympane, together with the wheel G I of the lower Axis, which wheel running into the other, moves the upper wheel and turns it about with the Tympane of the Axis D E, that the little Vessels draw the water from the Fountain, and raise it into the Vessel B; but because the water ought to be raised double the height in B, that it descends in C, therefore the upper crown, or ring of little Vessels, ought in like manner to be as long again (or doubly longer) and therefore that it may be carried about, and raised from the lower crown, or ring, being but half so big (or doubly lesser;) those little Vessels ought to be lesser, so that they raise upward in the same manner subduple, or half the water, yea, rather less, because of the resistance of the Engin, but the lower little Vessels receive double the water, or so much as suffices to move both the Wheels.

The lower Tympane may conveniently hang over the Well, or Pit, designed for it, within which the Crown or Ring of little Vessels descending, when they come to C, the little Vessels are unloaded successively, so that one side of the Crown is always full of water, and out-weighs the other side, and turns about the Axis: That if the upper Vessel B being filled with Water, which ascends upwards, it again flows into the lower Vessel A, and the lower part of the Engin is so accommodated, that the pouring out of the Water appears not by means whereof the lower Tympane is moved, and the Spectators may easily be deceived, thinking that Water only to descend which at once ascended, that therefore they may think it a kind of perpetual motion.

If the weight of the Water of the lower Tympane be doubly greater than the weight of Water which ascends to the upper Tympane, this Water may be raised to a double Altitude, and therefore a crown of little Vessels doubly longer must be used; and those little Vessels of the upper Tympane will be proportionally lesser in the same manner, *viz.* if the water be to be raised triple or quadruple higher, the little Vessels of the upper Tympane, or wheel, must be triple, or quadruple lesser than those of the under or lower Tympane, or wheel, so that the length of the upper Crown is made amends by the magnitude of the little Vessels of the lower Crown.

But

But the little Vessels of both Crowns may be made equal, and nevertheless the Water may be raised to any height, to wit, if the wheels G I which bite each other, be made unequal; for if the upper wheel hath its Diameter doubly greater than the under wheel, this will move that with a weight of water doubly less, and therefore a crown of little Vessels doubly lesser will be equal to the little Vessels of the upper Crown; I say, the same of any other proportion, triple, quadruple, *&c.* wherefore amends may be made divers ways for the height, and plenty of water ascending, either by means of a greater upper wheel, or by means of greater little Vessels of the lower wheel, or Tympane, or partly by means of the greater wheel, and partly of the greater small Vessels.

But if from all the Water in the Cistern A continually flowing, the greater part of it is to be raised in the upper Cistern B, as if you were to raise three parts of four of the water, and but one part only to descend, than the lower Crown must be 3 times as long as the upper Crown, and the little Vessels of the same must be at least three times lesser, if both the Axes of the wheels G and I be equal. But if the wheels G I be unequal, the proportion may be made fit another way; for if the lower wheel be three times greater than the upper wheel, the little vessels of the Crowns may be made equal, but the lower Crown ought to be three times greater; for in this case, while the lower wheel is turn'd about ~~only once, supposing five of its~~ little vessels to be fill'd, the upper Wheel is turn'd about thrice, and therefore fifteen of its vessels draw water, and in like manner 15 vessels of water they pour into the Cistern B.

Also both crowns, or chains, to which the little vessels are fastned, may be accommodated to one and the same upper wheel, but it will be necessary to fit to the wheel two wheels with Axes, as is declared before: But if the altitude to which the water is to be raised, be so high that it requires very great wheels, other wheels may be disposed in the middle between each wheel, which may be moved successively by the lower wheel, equally or unequally, according to the proportion of the quantity of water, or the magnitude of the little vessels; for this will be very commodious, as if the water be to ascend higher, we add to the Engin one, or more wheels, if not so high, we take away the same, making no mutation or alteration of the Crowns, or Vessels; moreover the vessels of both

crowns may be always equal, and yet the water may ascend to divers heights, the lower crown remaining the same and not altered, by only changing the magnitude of the upper crown; for as is said above, if the water ought to ascend 4 times as high as is the descent of the other, 'tis sufficient that the crown of the upper wheel be 4 times greater, or somwhat less; and the upper wheel G I, must in like manner be 4 times greater than the lower, or little more; for so the upper wheel will be moved 4 times slower, and will raise a fourth part of the water, the crowns, or chains, of both vessels being equal.

Likewise the Wheels and Axes may be multiplied together with wheels annext, and the chains, or crown, of vessels, so that one be put upon another; for we may make another wheel to exist on the Axis D E, which may be moved by the middle wheel G I, and furnish it with a wheel, and a chain of small vessels descending into the Cistern B, and drawing water from thence; moreover that water now raised into B, may from the crown, or chain H I again be raised either all, or at least, part of it into another Receptacle, or Cistern, higher, and from this into another as high as you please, all which we leave to the will of the industrious Artificer, since we have shewn so many ways, it may suffice.

Engin XI.

To empty standing Waters.

Fig. 107. A is a long jagged wheel joined together with strong pieces of Timber, designed for the drawing off, or draining of water; the length may be made at pleasure, according to the proportion of the breadth of the water, also it may be made so broad, that the whole Semidiameter from the Circumference to the Axis be immerst in water, yea, the Circumference may touch the bottom, for as much as the moving force of the wheel may be increast as you please, and as need requires.

From this wheel A, the Leaver B passing through the wheel, and the water extends to the Earth, or Shoar, where is erected a wooden receptacle C C; the wheel D is adjoined to the leaver.

leaver B, which comprises the wheels E and F, and these the wheels G and H, and these the wheel I.

The leaver of the wheel I reaches to K, where it hath a strong Iron Ring put about it, which is furnisht with holes through the Circuit, and stands out towards L, that it may receive L within it.

L Q is a Cylinder, whose end L is furnisht with a like Iron Ring bored through in the Circuit, only 'tis a little lesser or straiter than the ring K, that it may be thrust within it, after that the said end L is put within the ring K, both the rings are firmly bound by Wedges and Hooks of Iron driven in through each corresponding hole, that the Cylinder L Q, together with the leaver K, may be turn'd about: In M are Wedges, and Hooks of Iron, which are join'd to the two said iron rings K and L, and made firm, that the axis K and the Cylinder L may be turn'd together, the rope that draws is folded about the Cylinder L Q, which must be lengthned that it may pass above the wheel or pully N; to the rope is hung the weight O, of as many hundred pounds as you please, or necessity requires; this weight, while the rings K and L are firmly joined, turns about the wheel I, and this the middle wheels H and G, then E and F, and at last D and B.

The weight O, how great soever it be, after that 'tis turn'd about with his rope, it may be raised again, or by a man only, it may easily be done with the Engin called *Pancratium* P. which that it may be done, 'tis necessary that the end Q of the Cylinder L Q be not round, but square like the end of a spit, which being turned round, the little Engins are turn'd about, and 'tis bored through that it may receive a Nail, or a Wedge, but the end of the Axis of the lowest wheel of the *Pancratium* ought to have a square hole which agrees with the said end Q, that this may be put into that, and fastned with a Nail, or made firm with a wedg after that manner, that a Spit is thrust into the hole of the round machine, or wheel, that turns the Spit.

Then when the weight O is drawn to, I take away the wedges and hooks M, from the rings that are conjoined to K and L, that L may be freed from K, then I apply the *Pancratium* to the square end Q, and turn about the handle of the *Pancratium*, which when done, the wheels I, H, G, *&c.* rest, but the weight O is raised, and the leading rope is turn'd about the Cylinder L Q.

After.

After that the weight O is raiſed, join again and make firm one within another the rings K and L, but remove the *Pancratium* from Q, and the weight by its deſcent will again turn the wheels I, H, G, *&c.*

From whence it appears, that the chief Artifice is placed in this, that as great a weight as you pleaſe may be applied inſtead of a power, by means whereof while it is moved very ſlowly, it effects a ſwift motion in the extream wheel of the Engin; and again, by applying the *Pancratium* P to the Engin, whoſe Fabrick is declared above.

But becauſe perhaps it requires as much time to raiſe the weight O with the *Pancratium*, as is that wherein the ſame weight deſcends, and therefore great part of the Engins time is loſt by this effect; therefore I adviſe to diſpoſe another Axis T V upon the Axis L Q, and in the mean time while the weight O deſcends, and the Engin performs its effect, the ſame *Pancratium* being applied to the Axis T V, may raiſe another weight X, to be applied again preſently to the Engin, as the weight O comes to the bottom, to be taken up again by the ſame *Pancratium*, while the wheels are turn'd about by the other weight; for ſo the Engin, or Machine, will never ceaſe from motion, beſides that little time wherein the rope being looſ'd from the weight, is again turn'd about the Axis L Q, and the faſtning it to the other weight now raiſed above; yea, thoſe iron-Rings and Wedges will not require to be uſed, if ſo be you can uſe one continued Cylinder only M L Q, to which the rope may eaſily be wound about, ſince this will be free from the weight; Or likewiſe a double rope may be uſed, one of which without weight (or at leaſt but a little) may be wound about the Cylinder, while the other is roled and drawn downward by the weight.

This Engin if it be made after the foreſaid manner, it will be indeed more ſimple and eaſie, and ſerve for many other uſes; as for Example, the lower wheel B will eaſily be applied to a vertical wheel, which will likewiſe turn about ſwiftly a Hand-mill; in like manner there may be added to the Axis B D, pins to take up Peſtles, wherewith mineral Veins may be pounded, or Gun-powder, *&c.* as is declared before, alſo there may be many other wheels to turn about to wind ſilver Thred, and other ſuch like, as will appear to the Conſiderate.

Engin

Engin. XII.

By whose means the water always ascends to any given height, supposing also it be but a small stream of water, so it be but constant.

Fig. 108. LEt there be a large Receptacle, or Cistern A B, into which the water constantly flows through some Channel, or Pipe C, below that cistern make two other cisterns G H, and X Z, in two several places of sufficient bigness, according to the proportional quantity of water, which must descend by turns from the cistern A B, into those two lower cisterns, as will appear by and by, and for that cause the Tubes F G, must descend from the bottom of the cistern A B, into the cistern G H, and Y X into the cistern X Z, and these cisterns must be furnisht with a cover, and the cover must come close to the side, for they ought to be every where close and shut, but the cistern A B must be open; those Tubes upon the bottom of the cistern A B, must have flaps E and D, so that their mouths may be shut or open: The cistern G H will need another Tube in its lower part, furnisht likewise with the flap I, and the same must be as near as may be of the magnitude with the Tube F G and Y X; the same must be performed in the other cistern X Z, which in like manner must have the like Tube Z furnisht with a flap.

Through the cover of the cistern G H, a small hole being made, descends a rod of mettal O M fitting the hole, to whose lower part the brass vessel M is soddred fast being inversed, to wit, so that the open part of the vessel, or bucket, look downwards, and to the other end of the rod O, is fastned the arm O N, which is so posited in N, that it may easily be moved upwards or downwards; to the same little arm O N is affixt such another like rod, which descends in the same manner into the lower cistern, and sustains the weight L within the cistern; finally, that little arm is furnisht with a little wing *a*, hindering its coming upwards, and 'tis intercepted with a double staff, or spear, or between the notch P N, 'tis interrupted by the little arm *b* a thwart; this kind of staff, or notch, on its up-

perr

per part P, is fastned to another staff or leaver P Q V, and to the same leaver in Q, is knit or fastned another rod I Q R, by whose means the flap I is opened and shut: Furthermore the leaver R S T is moveable about the centre, by help whereof while the flap D is lifted up or opened, the other flap E is deprest and shut, and *vice versa.*

These things being thus disposed, that some determined part of the water which descends into the Cisterns G H and X Z, may ascend again to any given height, (as for example) into the upper cisterns A and B; above the cistern G H make another vessel, or cistern C E, yet so, that it may be somewhat lower than the superficies of the water that is in the cistern A B, and let it be close shut every where that no air enter in. Through its bottom, and through the cover of the cistern G H, let the Tube C H descend reaching almost to the bottom of the cistern G H, and almost touching the cover of the cistern C E. Then from the same vessel C E, must ascend two other Tubes into another vessel like that before, to wit, the Tube E F, which almost touches the bottom of the vessel C E, and the cover of the upper vessel D G; and the Tube C D, which ascends from the cover C of the lower vessel, almost to the cover of the upper vessel in D; altogether in the same manner, two other Tubes G A, D H, must ascend from the vessel D G, into the vessel H A. Lastly, in the uppermost vessel A H, which much be open without a cover, fit a *Scyphon* A P, through which the water is derived, or conveyed, into the cistern P Q designed for use.

Above the cistern X Z, in the same order must be placed so many, and altogether the same vessels furnisht with the same Tubes.

Then from the cistern A B, by opening the flap E F, the water flowing into the lower cistern G H being close shut, 'tis compell'd by the comprest Air to ascend through the Tube A C, into the upper vessel C E, the Air being excluded in the mean while from it by the Tube C D. But in the same time in which the vessel C E, is fill'd with the Tube A C, its breadth being less than the breadth of the Tube F G, the water always fills the cistern G H, and forces the inverss bucket M to ascend, until at length by means of the leaver, or arm O N, hitting against the little arm *b*, raises the staff P N, and the same work interposing P Q V, opens the flap I, and shuts the flap Z, and likewise by means of another leaver R T S, the flap E is shut, and the flap D opened,

pened. Then from henceforth presently the water from the ciſtern A B, begins to flow into the other ciſtern X Z, and from thence aſcends and fills the upper veſſel L, and at the ſame time by opening the flap I, the receptacle G H is emptied of all the water, and therefore the inverſe bucket M deſcends again, and the weight L in the middle, and the wing *a* draws down again the ſtaff P N, and ſhuts the flap I, and opens the flap Z; and likewiſe ſhuts the flap D, and opens the flap E, that the water may again flow into the receptacle G H; then by condenſation, or preſſing of the Air interpoſing, the water which now ſhould aſcend into the veſſel C E, is forced to raiſe higher into the veſſel D G, which being filled, they preſently change turns, and the flaps Z and E are ſhut, and I and D are opened, and ſo the water aſcends from the veſſel L into the veſſel M; this in like manner being fill'd, the flux of water is changed, and the water aſcends from the veſſel D G, into the uppermoſt veſſel A H, afterwards from the veſſel M, into the veſſel B, while in the ſame time the veſſel A H is emptied by the *Scyphon*, the water flowing into the common receptacle Q P; then again the veſſel C E is fill'd, and after that the veſſel L, and in the ſame order alternately new water aſcends from one veſſel to another, as often as the flaps change turns, being ſometimes open and ſometimes ſhut.

Where 'tis manifeſt, if the veſſels be increaſed one above another, the water will be forced to any height although but ſlowly; and the foreſaid veſſels ought to be ſo far diſtant from one another, that the height of one above the other, doth not exceed the height of the receptacle, or ciſtern A B, above the ciſterns G H, Z X, or the perpendicular altitude of the fall of the water which we conclude to be conſtant. Moreover the Tube C D ought to be fitted with a flap, or thin board in C, ſo that when the veſſel C E is filled with water, the flap or board may ſhut it, that the air break not out through the Tube into the veſſel above, for ſo this air being compreſt, forces the water from the veſſel C E to aſcend into D G; I ſay, the ſame of the Tubes C D and D H, *&c.* alſo this artifice may be otherwiſe diſpoſed, as ſhall ſeem meet to the induſtrious Artificer.

Mechanick Powers.

OF
CIRCULAR MOTION.

BOOK. VIII.

PROPOS. I.

Of mix Motion from Circular and Right, or from two or more Circular.

WHile a Wheel is moved upon a plane superficies, I say, the same of a Globe, or ball, the central point only of the Wheel, or Globe, is moved with right motion, all the other points, or parts of the moved Wheel, or Globe, are moved with a mixt motion of circular and right.

This motion of rotation on a plane hath admirable properties throughout, which being rightly percieved, it will be easy to understand the other mixt motions: Wherefore we make a beginning from it; but yet we first advise that circular motion truly and Physically consists of many right lines, nevertheless in this place we will consider it even as if it were altogether simple motion, but where it will be needful to consider those small parts of right motion of which ci:cular motion is compounded, there we will make particular mention.

Fig. 109. Let then the Wheel, or orb, be A Z L Q, insisting on the Plane A D on which it is to be roled, or turned, and let the right line A D be equal to the arch A Q, so that while the Wheel is moved towards D, the point Q may touch in the point D: In this motion 'tis manifest, First, that the Centre of the Wheel O is moved by the right line O E, for since the Wheel always

always touches the plane in ſome point, and the Centre O is always equally diſtant from the points of the Periphery, which ſucceſſively touch the plane, the Centre O will always be in the line O E, and when Q is come to D, the Centre O will be in C, and the Centre O always inſiſts perpendicularly on the point of Contact.

Secondly, 'tis manifeſt that any other point is moved with a mixt motion; for if, for example, we take the point L, over and above the motion of the centre 'tis moved towards Y, ſo that if the Wheel ſhould not be turn'd about the Centre O, but only moved upon the plane, always touching the Plane A D in the point A (which is to move only by the motion of the Centre) the point L will be moved by the right line L Y, and while A is in D, E will be in Y, O will be in C, and ſo any other point of the Wheel will be moved by a right line parallel between the extreams A D, L Y. In like manner, the point L, or any other, will be moved only by a circular motion, if the Centre of the Wheel O be altogether immovable, to wit, L will be moved by the arch L K *e*, *&c.* A, by the arch A T, *&c.* alſo the point N will be moved by another arch of a leſſer circle, *&c.* Since therefore the Wheel is moved together by the motion of the Centre towards E, and by the motion of the Orb from L in Q, and from Q in A, *&c.* the point L will be moved with a mixt motion from both, to wit, of the Centre, and of the orb, that is, of right and Circular; which may be ſaid of any other point, the centre excepted.

PROPOS. II.

Any point, except the Centre of the foreſaid Wheel, or globe, deſcribes a crooked line, which is not circular.

Fig. 109. FOR example, take the point L, and that you may get the line which it deſcribes, divide the arch of the quadrant L Q in as many equal parts as you pleaſe, ſuppoſe three, L K, K A, H Q; alſo divide the line of the plane A D into ſo many equal parts, to wit, three, then the point L having paſt over the firſt part of the arch L K, if it were moved only by the motion of the orb, it will be in K; but

if it were moved only by the motion of the centre it would be in V, therefore let the right line M I be parallel to L Y, and let K I be equal to L K, or A B, without doubt the point L will be in I; For the motion of the orb gives L K, or M K, but the motion of the Centre gives L V, or K I. In like manner, in passing over the arch K H, the same point L will be in G, if you take H G equal to A C, or L V, and parallel to L Y; For the motion of the orb gives L H, or N H, and the motion of the centre gives A C, or L V, which is equal to H G. Lastly, in passing over the arch H Q, the point L will be in E, to wit, if Q E be taken equal to A D, or L Y, for the motion of the orb gives L Q, or O Q, and the motion of the Centre gives A D, or L Y.

Secondly, take the point A, and that you may have the line which it describes, divide in like manner the arch of the quadrant A Z into 3 equal parts, to wit, in T and Y, then in passing over the arch A T, if the point A be moved only by the motion of the orb it will be in T; but if it be moved only by the motion of the Centre it will be in B, therefore if you take T S equal to A B, the point A will be in S. In like manner, in passing over the arch T Y, if the point A should be moved only by the motion of the orb, it would be in Y; but if it should be moved only by the motion of the Centre, it would be in C, wherefore if you take Y R equal to A C, it will be in R. Lastly, in passing over the arch Y Z, it will be in P, if so be you take Z P equal to A D.

From hence it appears, that those are *Curve*, or crooked lines, and yet not circular; wherefore some call them by a proper word, *Whirling-lines*; you may call them as you please.

Also by this you see that the point L, which is opposed to the point of Contact A, is so moved, that the motion of the orb, being added to the motion of the Centre, for each motion is in the antecedent, but neverthelesss the point of contact A, is so moved that the motion of the orb is taken away from the motion of the Centre; for the motion of the Centre is in the antecedent, but the motion of the orb is in the Consequent, notwithstanding because the motion of the Centre, is greater than the motion of the orb; it follows, that the point A Simply and absolutely will be moved in the antecedent, to wit, towards D, neither will it wholly go back; to wit, it will be moved towards D, only so much as is the difference X S, be-

tween

tween the motion of the orb A T or K T, and the motion of the Centre A B or S T.

Alſo take notice that the point L deſcending in the arch L Q, will be ſo moved that the motion of the orb adds to the motion of the Centre, the right ſines of the arches it paſſes over. So the motion of the orb L K, adds the right ſine M K, to the motion of the Centre K I or L V; and the motion of the orb L H adds the right ſine N H, to the motion of the Centre H G or L V, *&c.* But neverthelefs the point A oppoſite to the point L, to wit, the point of Contact with the plane is ſo moved in the arch A Z, that the motion of the orb takes away the right ſines of the motion of the Centre, ſo the motion of the orb A T, takes away the ſine T X from the motion of the Centre T S or A B, to which T S is equal. But now the point Z is ſo moved through the arch Z L in aſcending, that the motion of the orb adds the verſed ſines to the motion of the Centre; thus the motion of the orb of the arch Z *d*, adds the verſed ſine Z *e*, to the motion of the Centre D F, wherefore if you take D *f* equal to A B, the point Z in paſſing over the arch Z *d* will be in *f*, likewiſe in paſſing over the arch Z *h*, it will be in *g*, for the motion of the orb adds the verſed ſine Z *m*, to the motion of the Centre A C, equal to which *h g* being taken, and in running through in the arch Z L, will be in Y, for the motion of the orb adds the verſed ſine H O to the motion of the Centre L Y; moreover the oppoſite point Q ſo deſcends through the arch Q A, that the motion of the orb takes away the verſed ſines from the motion of the Centre; ſo in paſſing over the arch Q *n*, the verſed ſine Q *t*, is taken away from *n r*, which is put equal to the motion of the Centre A B, and ſo the point Q will be in *r*; but in paſſing over in the arch Q *p*, the point Q will be in B, to wit, *p b* being taken equal to the motion of the Centre A C, for it takes away the verſed ſine Q I; Laſtly, in paſſing over the arch Q A it will be in D, and ſo the verſed ſine Q O will be taken away from the motion of the centre A D.

Hence you eaſily ſee the deſcription of lines, which each point of a circle runs over being roled, or turned, on a plane. Alſo you ſee the line which the point L deſcribes in deſcending, that is, to anſwer the line L I G E, and is equal to the line Z *t g* Y, deſcribed from the point Z in aſcending; and the line A S R P deſcribed from the point A, anſwers, and is equal to the line Q *r b* D

deſcribed

described from the point Q, that ascending, but this descending.

Hence also it is that the points L and Z are moved most swift, but the points A and Q most slow; and the point L is moved Swiftest of all in the beginning, afterwards more slowly: But the point Z by inverse proportion is moved slowly in the beginning, and successively more swift. In like manner the point A is moved slowest of all in the begining, afterwards successively more swift, but the point Q by inverse proportion is moved more swift in the beginning, and in the end most slow. Wherefore all the points indeed are moved with unequal motion, while they run over the quadrant; but the whole quadrant being compleated, the motion of the point L, and of the point Z come to be equal, so also the motion of the point A and of the point Q.

Moreover you see the Centre O to be moved swifter in the beginning than the point of Contact A, but in the end more slow, and the space which the point O dispatches from O in C, is greater than the space which the point A dispatches from A in P.

Also you see that no point is moved with an equal motion, except the Centre, but by an accelerated or a retarded motion; so that from two opposite points one is moved with an accelerate, motion, as the point A, but the other with a retarded motion, as the point L.

At length if you take the point B 45 degrees, that is, which dispatches the greatest space of all, for the motion of the Centre O S equal to A D, is added to the motion of the orb from B in Q.

Fig. 110. Thirdly take a point within the Circumference, suppose the point F: And that you may find the line which it describes, make the Circle F 4, G 9, and divide the quadrant F 4 into 3 equal parts marked in the points 2, 3, Then while the motion of the orb comes to 2, the motion of the centre A B or 2, 5 is added to the sine 2, 1 of the arch F 2: In like manner while the motion of the orb comes to 3, the motion of the centre A C, or 3, 6, is added to the right sine H 3. Lastly while the motion of the orb dispatches the quadrant F 4 and comes to 4, the motion of the Centre Q 7, is added to the right sine Q O, and describes the line F 5, 6, 7: In like manner, by what hath been said, you may easily find the other lines

lines which the other points of the ſame leſſer circle contained within the greater deſcribe. So the point 4 deſcribes the line 4 M N P, while the verſed ſine 4 R is taken from the motion of the Centre A B or L M; and the ſine 4, 5, from the motion of the Centre A C or T N; and laſtly the verſed ſine 4 O from the motion of the Centre A D or G P.

PROPOS. III.

A leſſer Wheel included in a greater is ſo moved, that in it the motion of the Centre is greater than the motion of the Orb.

FOR while the motion of the Orb is made through the whole quadrant F 4, the motion of the Centre is made through the whole right line O V, which certainly is greater than the arch of the quadrant F 4. In like manner the motion of the orb through the quadrant 4 G, is leſs than the ſame motion of the Centre O V; But how each point of the quadrant 4 G anſwers each point of the plane G P, upon which the quadrant of the leſſer wheel is underſtood to move, when the plane is greater than the quadrant, is that famous difficulty which obtains the name of *Ariſtotle's* Wheel, becauſe *Ariſtotle* hath propoſed it in his 24*th.* queſtion of *Mechanicks*, which *Blancanus* hath explicated, and *Merſennus*, *Galileus*, *Cabens*, *Fabrus*, and others have expoſed to view.

PROPOS. IV.

The difficulty of Ariſtotle's Wheel,*that is, the motion of the leſſer Wheel when this is directed by the motion of the greater, and the motion of the greater; when this is directed by the leſſer, is beſt ſolved and unfolded from the nature of this Circular motion, ſo far as Phyſically 'tis compounded of many right lines.*

LEt the Wheel be A C H inſiſting on the plane C E, whoſe radius is A C, and within this another leſſer, ſuppoſe it ſubduple, A D B is included, whoſe radius is A B; and let the plane

plane C E be equal to the arch of the quadrant C H, ſo that while it is turned upon the plane C E, each point of the arch anſwers each point of the plane; When therefore the leſſer Wheel in this motion is carried away by force by the greater, ſurely the point D will come to F, when the point A will come to G, that is, the radius A D will meet with G F.

Therefore the whole difficulty will depend on this iſſue, that B F will be double the arch B D, if ſo be the points of the arch B D ought ſucceſſively to correſpond with the points of the plane, or of the line B F, or each point of the arch B D anſwers each point of B F, or each point of B C anſwers two of B F, or the altern points B F by skips remain wholy untoucht; for neither doth any thing elſe ſeem to remain which can be ſaid, in truth none of theſe ought to be ſaid: For if it be ſaid in the firſt place, that there is ſo many points in the arch B D, as there are in the line B F, which cannot be ſaid, ſince this is doubly greater than the arch: But if it be ſaid ſecondly, that each point of the arch B D correſponds to two points of the line B F, it follows that the plane C E, is double the arch C H, when notwithſtanding they are ſuppoſed equal; for when the points B C, are in the ſame radius A C, if the point C touch the point of the plane next following towards E, it will not be perpendicular to the plane C E. Surely A B when it touches the point of the plane B F in B, and is perpendicular to the plane, alſo A C which is ſuppoſed a right line will be perpendicular to the plane C E, which is parallel to the plane B F: Therefore it toucheth not the plane in any other point than in C, which if it ſhould touch it would be alſo in the other next following point; therefore every point of the arch C H, touches two points of the plane C E, therefore the plane C E will be double the arch C H. Moreover it cannot be ſaid that the altern points, or every other point of the plane B F, are toucht as it were by leaps, and not the other intermediate points, for at the ſame time in which ſome point of the plane C E is toucht anſwering the untoucht point of the plane B F, ſome point of the arch B D without doubt touches the plane B F, therefore it touches the point of the plane B F, which correſponds to the point toucht by the greater Wheel in the plane C E, for if it ſhould not touch the Centre A, ought to be elevated above the line A G, and conſequently the greater Wheel will not touch the plane C E, which is againſt the ſuppoſition; therefore no point of the plane B F remains untoucht.

More-

Moreover this difficulty hath great force againſt thoſe authors who affirm that a body may be compounded of Mathematical points, whether finite or infinite, as may appear to the conſiderate, concerning which I ſhall ſay no more at this time.

Neither can it be ſalved by thoſe who admit proportional parts to act infinitly; for while they ſay the point of Contact may be made in an undetermined part they ſpeak unconceivably; for ſince the point of Contact is real and ſingular, I cannot ſee how it can be indeterminate, which if it be determinate, that is, in this place and not in another, than it becomes determinate in this part, and not in another; moreover 'tis ſomething which touches diſtinct from all that which touches not; but to touch, and not to touch, are contradictions, and how can that be ſomewhat indeterminate from all that it touches not? Add, that there is no part in the plane B F, whether determinate, or indeterminate, which remains untoucht; how then does each part of the arch B D anſwer each part of the Plane B F, when there are as many more in that, as in this?

Some recur to the greater velocity whereby one Wheel is moved than the other, but if they ſpeak concerning the motion of the Centre 'tis falſe, for there is one and the ſame Centre A to each; but if they ſpeak of the motion of the orb they do not evade the difficulty by that, for the queſtion is, why the arch B C although it be moved ſlower than the arch C H, nevertheleſs it is meaſured by an equal ſpace, which ſucceſſively touches the whole.

Father *Faber* recurs to the incommenſurability of the plane, to wit, of a right line with the arch of a Circle, for he ſays, that although the right line C E be ſuppoſed equal to the arch C H, notwithſtanding they can by no means agree, howſoever they are divided; but I ask whether they conſiſt of an equal number of points, ſurely ſince they are equal, they muſt at leaſt conſiſt of an equal number of points, to wit, of Phyſical ones; or then all are toucht by the arch B D, or ſome remain untoucht, and ſo the difficulty returns: He ſays, the points of the plane B F are right, or ſtreight, but the points of the arch B D are crooked; and although a right point be equal to a crooked point, and although one whole point is toucht by another point, yet notwithſtanding they are not toucht alike, becauſe the extenſion of the one is not analogous with the extenſion of the other, and he alleadges an example.

It may be objected against this explication in the first place freely, that each Physical point composing a Physical and real plane may be made; B F is a right line, but each point composing the periphery of the Wheel, or the arch B D, or *Fig.* 111. C H is crooked, for why cannot the same points of substance, or matter, which compose a superficial plane, compose a crooked plane? Moreover, when a rod of Iron, or a plate of metal is made crooked by bending, are there not the same points, if not more in the crooked plane after bending, as was in it when it was a superficial plane? Secondly, also if we admit the points B F to be plane, and the points B D to be crooked, and so these touch not in an adequate proportion each point of the plane B F, neverthelefs are there not little vacancies between one crooked point and another, which for that cause leave untoucht the points of the plane A, B, C, *&c*? Besides, that those crooked points touch not adequately, to wit, in all their virtual parts the plane points A B C, doth not cause that in each instant wherein the Wheel is moved by the motion of the orb, the new crooked point of the Wheel ought not to answer to the new point immediateatly next to that of the plane; if so be the point of the Wheel is equal to the point of the plane.

The same difficulties occur if the lesser Wheel be concieved to be so moved, that its Periphery be equal to the plane on which it insists; for then the greater Wheel will be so moved that its Pheriphery will be double of the other plane which it passes over; as if the Wheel A B D be turned upon the plane B I, and since the arch B D is equal to the plane B I, the point D will arrive in I, for then the point H of the greater Wheel at the the same time will arrive in L, when notwithstanding the arch C H is as great again as the plane C L; wherefore each point of the plane C L ought to answer to two points of the arch C H.

Besides in this motion, to wit, when the motion of the greater Wheel, is govern'd by the motion of the lesser Wheel, somethings happen yet more singular; for in the first place, some points of the greater Wheel go backward, as you may see after, that the Centre of the Wheel A is come to K, and the point D is come to I, the point H will be in L, and consequently go backward: In like manner the point of Contact C goes backward after that 'tis come to M, and consequently all

all the points of the Quadrant C H go backwards, but the middle point R, chiefly goes backward most of all, for it goes down from R to S as appears, but the other points go backward here and there less and less successively.

Secondly, some points neither go forward nor backward, *viz.* in the end of the motion, when the point H comes to L, 'tis distant the same measure as before, from the same term, *viz.* from the line C N; So the point X will be in Z, and the point Y will be in V, and so in the end the motion gains nothing of space towards P; notwithstanding 'tis to be observed, that those two points sometimes go forward and sometimes backward, so the point X in the beginning goes forward but afterwards goes backward, but the point Y in the beginning goes backward, and afterwards goes forward, but because they go back the same space as they go forward, they acquire no space in the end of the foresaid motion.

Thirdly, all the other points of the arch Y Q N X go forward, that is, in the end of the motion they have acquired space towards P; so the point N will come to P, the point Q to O, the point T in *b*, *&c.* nevertheless all these points go not always forward, as appears from what's said in the 2 *Prop.* but because they go forward more than they go back, therefore in the end of the motion, it appears that they have gone forward; In like manner we will shew, that those points which are in the arch X R Y, and which go backward, do not continually, or always go backwards, but their going backwards appears in the end only, because they go back more than forwards.

These things being noted and observed, it will not be hard to explicate all those motions according to our doctrine; for to that which is the chief head of the difficulty, we say we ought not to consider that mixt motion, to wit, of the point H (while the whole arch C H, passes over only the space of the plane C L] as one only and simple motion, for it is really many and various, for as much as 'tis compounded Physically, of many right motions, to wit, 'tis compounded in the first place, from those right motions which compound Circular motion, then 'tis compounded of those and of another right motion, because the Centre A, common to each wheel is moved: From whence it comes to pass, that the point H, in the motion of the orb from H to C, while it goes backward

together alſo, while it goes forwar d, 'tis carried by the centre A, and as it were carried away by force towards P; notwithſtanding it doth not go forward and backward, in the ſame Phyſical inſtant, as Father *Cabens* contends for in his book of *Meteors*, (for tis impoſſible for the ſame movent, to be moved by two oppoſit motions together) but ſo that ſome Inſtants it muſt go forward, and in others backward, which muſt needs be ſaid of ſome points, as X and Y, as we have obſerved before, to wit, if the whole time, in which the point H is moved, from H going down to L, be ſuppoſed to be 12 particles, we ſay, 'tis moved; for example, 5 of thoſe parts by a right motion from H, or from A in P, that is, by ſmall parallel lines of A P towards P; and the other 7 particles to be moved in the oppoſite part in going backward, from whence it comes to paſs, that when the regreſſion is greater than the progreſſion, in the end of the motion the regreſſion only appears, to wit, when it comes in L, and becauſe thoſe particles of time wherein ſometimes it goes forward and ſometimes backward, in each ſhort time are almoſt innumerable and inſenſible, becauſe of the brevity, and makes the progreſſion and regreſſion by turns, any motion and time being aſſigned will appear only in the end of the progreſſion if it be greater, or only in the regreſſion if the progreſſion be leſſer.

Hence you ſee nothing hinders but that the points of the plane C L, are in number ſubduple of the points of the arch C H, when notwithſtanding that arch paſſes over only that plane C L; for by the method explicated by us, doth two points of the arch very well ſucceſſively touch one and the ſame point of the plane, to wit, if in the firſt inſtant the point C of the arch C H, while the arch D is carried by the centre A, touches the point of the plane C, which in the anticedent inſtant it touched not; and in the ſecond inſtant, another point of the arch next to C, touches that ſame point of the plane C, while the motion of the orb goes backward, and, as I may ſay, creepeth upon that point C: Then again in the third inſtant, the third point of the arch touches the ſecond point of the plane, and in the fourth inſtant, the fourth point of the arch creepeth upon that ſame ſecond point, *&c.*

But it may be ſaid that cannot be, becauſe the centre A ought to aſcend upon the line P A, I ſay, this is abſur'd, if the motion

motion and the circle be consider'd Mathematically, but not if it be considered Physically, for it ascends and descends always insensibly; and that by some small part of the plane only, and the compression and tension of the wheel, without which it cannot be Physically moved upon the plane, as will clearly appear from what follows.

Therefore all occasion of Error proceeds from this, that they would apply to Physical motion and Physical quantity, a motion Mathematically considered, or quantity and the nature of a circle, which is not given after a manner conceivable; moreover they consider the motion of the point H, by the crooked line from H in L, all one as if it were one only motion, when notwithstanding 'its manifold and divers; like as they consider, for Example, the form of mixt, as it were one simple form distinct from the forms of those Elements compounding the mixt, when nevertheless 'tis not something absolutely distinct from them, but only in the manner as I shall shew in its place; wherefore also that mixt Motion may truly be considered as one simple motion by one only crooked line, because the rectitude of the small parts of which 'tis compounded is not sensible, like as the least particles of Elements are not sensible in mixt; but notwithstanding 'tis truly composed of the motion of the smallest right lines, since in nature there cannot be given a motion perfectly circular, as is shewn before.

PROPOS. V.

A Globe, or Wheel, while 'tis moved upon a plane, whether Horizontal, or inclined, is moved by a mixt motion of a circular and a right, and is determined according to a circular motion from the impediment which is in the contact of the plane on which 'tis moved.

Fig. 112. THat 'tis moved with a mixt motion, appears from what hath been said; and that the circular motion about the centre arises from the impediment in the point of Contact; to wit, from some resistance and rubbing of the plane is proved, because the circular motion is not the natural by *Prop.* 4. Therefore it ought to arise from somthing without;

out; but circular motion as ſuch, is cauſed from impediment only ſucceſſively determining new *Impetus*'s by new tangent lines; but in our caſe when the centre is not impeded, but is alſo moved, it cannot be an impediment to the centre, nor to any thing that adhears to it, ſince nothing there is without it, therefore 'tis impeded from the plane only. Secondly, 'tis proved, becauſe if any one puſh forward the Globe A by a puſh tending from C to D, in a line parallel to the plane B E, the Globe nevertheleſs is turned on the plain while it goes forward in E, but 'tis rolled in vain, unleſs it ſuffers ſome reſiſtance in the contact B; for why is not the whole moved by a right motion, if ſo be its *impetus* is impreſt by a right line, and parallel to the plane B E?

You will ſay 'tis eaſily moved, if it be moved by the mixt motion, from the right motion of the Centre and the circular of the orb, but why is it moved ſo eaſily? Moreover the Centre A, doth not more approach to the Centre of the Earth, by this that the Globe is moved circularly, for 'tis always diſtant to the Semidiameter A B, in the Horizontal plane B E: And the impulſe when it is by the right line C D, is eaſier deſtroy'd if the Globe be moved by the motion of the Centre, together with the motion of the orb, than if it be moved only by the motion of the Centre; yea, 'tis eaſier deſtroyed if it be moved by both motions than by one only; but chiefly becauſe the motion of the orb is not meaſured from that *Impetus* by a right line, but only by the motion of the Centre.

You will ſay, when it deſcends by an inclined plane, it deſcends eaſily, if it be moved together by the motion of the orb: For ſince in this caſe the Centre of gravity is without the line of direction towards the end of motion, 'tis determined from its Centre, or from its gravity to ſuch motion.

I anſwer, neither in this caſe ought the motion of the Orb to move, if there be no reſiſtance of the plane, for the reaſons are muſter'd up; for by this that 'tis moved with a circular motion, it comes not nearer the centre of the Earth, nor to the end of motion, for by how much the motion of the upper points are accellerated, by ſo much the motion of the lower points are retarded by that motion of the Orb, as appears by what is ſaid; therefore ſuch motion is in vain, when no impediment is taken away, for *Impetus* acts only to take away impediment, as is often ſaid; therefore if there be no impediment

diment in the point of contact, why doth the Globe always insisting in the same point on the plane, creep not on the plane? Doth not the *impetus's*, whether they be violently imprest on the Horizontal plane, or by their natural gravity on an inclined plane, obtain their end in the same manner, yea, easier, as is said?

Surely if a Globe be stript of all gravity, and then receive some impulse from without by a right line, and should this Globe be in a vacant place, or in such a place wherein it suffers no resistance to motion, or no more in one part than in another, there would be no reason why it should move by the motion of the Orb, but it would be moved only by the motion of the centre, by a line determined from the imprest *Impetus*, whatsoever the same be, whether Horizontal, or inclined, or Perpendicular; for why should it rather move in one part than in another.

You will say from the foresaid Experiments, that while a Ball is thrown through the Air, 'tis moved with a double motion, to wit, of the Centre, and also of the Orb; and yet in the Air, there is no rubbing or scratching with the plane, nor no impediment; yea, it seems, if the resistance which is of Air, 'tis equal about the Ball, that therefore it should not move rather in one part of motion of the Orb than in another.

I answer, the Ball thrown is often so thrown, that at the same time wherein the *Impetus* is imprinted before 'tis separated from him that throws it, is not imprinted by one right line only, but many *Impetus*'s are imprinted successively by many lines which compound some crooked line, for the Arm, or that which casts the Ball, while it casts it, is not moved by a right motion, but by a circular, that is, the Ball being separated from the Arm, while those *Impetus*'s are propogated in it, and new ones produced by the same lines, the Ball must necessarily be turn'd round about its centre. Hence it is that oft-times also a Ball is a little turn'd about its centre, if it be cast by one continued impulse by a right line, as you may observe: Besides that 'tis always but little turn'd, because 'tis never made so Spherical and perfect, but the Air resists more one part than another; add, that if it be not truly Homogenious, or all alike, so that the centre of the figure altogether agrees with the centre of gravity, since it can scarce be cast by that precise line which joins each centre, if it be not cast by this line, and even, so

ſo that the centre of gravity be right before, and preſently is ſeparated from the Thrower, or likewiſe if it be let drop freely, and falls from on high, it turns it ſelf until the centre of gravity be placed in the formoſt part of the line of Direction, and ſo it contains the impetus of rotation which is likewiſe proſecuted towards that part: And this is the reaſon why things that are thrown,or caſt through the air, are moved with a mixt motion of right from the Centre, and of mixt from the orb, and alſo of thoſe that fall of their own accords; hence a Cylinder whoſe heavier part declines downward, while it falls of its own accord from on high, is not turned about the Centre,but ſometimes about the axis, from the unequal reſiſtance of the ambient air.

PROPOS. VI.

In the deſcending of heavy bodies on an inclined plane, or through the free air, the motion of the orb, hinders not the motion of the Centre.

'TIS proved, becauſe the impediment which determins the Circular motion in the Globe, is not in its Centre, but in the Periphery, to wit, in the contact with the plane. or in the contact of the ambient air in that part to which the air moſt reſiſts; and this impediment hinders indeed the motion of the whole Globe, and at the ſame time determines in it the Circular motion; but that circular motion hinders not,nor retards the motion of the Centre, which is like manner tends downwards, whether the Globe be moved circular or not.

Hence one impetus deſtroys not another, unleſs when the impediment of the motion of the Centre deſtroys the natural impetus, and the inclined plane, or the air while it hinders the motion of the Centre, and deſtroys its natural impetus, produces according to the laws of reflexion another impetus by the tangent, and when this impetus produces ſucceſſively a new one by a new tangent, it makes the motion mixt, or really double, to wit, the motion of the Centre and of the orb.

And

And you may obſerve in motion on an inclined plane, not only the motion of the centre to be accelerated, but alſo the motion of the orb, becauſe when the motion of the orb is produced from the impetus, by the reflection from the direct impetus, if the direct impetus which moves the centre be greater, the reflected impetus is alſo greater.

Alſo you may obſerve in this motion all the parts to move with unequal motion, as may be gather'd from what has been ſaid; from whence 'tis confirm'd again, that they are not moved by an intrinſick principle, for this would be alike efficacious, or powerful in every part and ſo would produce an equal effect in them all.

Hence you may gather the reaſon of the Experiments following, in which this mixt motion appears from the right and circular about the proper Centre, or Axis.

Experiment. I.

Play Boys make ſhort darts with a point, in one end whereof there is a ſlit cut, and paper folded like a fourfold wing, and put into it, while this quavers, or ſhakes, the point goes before, and the paper ſo hinders the deflexion that 'tis the cauſe that while the dart tends rightly to the mark, 'tis turned together about the proper axis: The reaſon this, becauſe the air while 'tis ſtruck by thoſe wings, reſiſts the motion, which otherwiſe would carry the dart, by a right line, and it quavers to and again and hits on the ſides of the Wings, and this certain reflection together with the dart, is converted into a circuit, ſince this motion is eaſy to the dart and hinders not the right motion; the ſame may be ſaid of an arrow.

Experiment. II.

The like *Phænomena* you may obſerve in thoſe flitting reeds, which Boys alſo play with, for they fix 3 or 4 feathers into wood, or a bony ſheath, which while they ſtrike the air, they force that wood or Cylinder to turn it ſelf about its proper Axis; but if it be furniſht with only one feather, this circular motion will not be; likewiſe if any feather be broke, or not enough ſever'd from the other, the circular motion ceaſes: But if the feathers are much ſever'd from each other, the motion

is slower, *viz.* as well the right motion of the axis, as also the circular motion about the axis: And the feathers ought to be so fitted rising from the bottom to the top a little bent, and made crooked increasing the severing or parting: The reed or little Cylinder of wood always goes before in the motion, and the motion of the Axis ascends more swift, and the circular motion about the Axis less swift; moreover after the ascent 'tis turned downwards, and the Axis descends with a slower motion than before it ascended, but with a swifter motion about the Axis: And the reed, or little Cylinder, ought to be short and weighty, especially in the end that goes formost, and the feathers must not be too long.

Like to this, is that motion, which boys running make with a double stick, furnisht with a veil, and as it were a little mill turning about the centre, which is fixt to the moveable Staff, or Stick, for those veils, while they run in the air concieve a conversion and circular motion, which is joined with a right motion.

The reason of this *Experiment* appears thus, in the first place, that reed, or little Cylinder, furnisht with feathers goes before with a right motion, because 'tis heavier and endued with a greater impetus, and therefore leads the feathers whose motion the air resists more; and in resisting it comes to pass that they are reflected from themselves, and so turned about in a circuit together with the little Cylinder. From the air then reflecting, the impetus of the Feathers is imprinted successively by a new tangent, and from this impetus the feathers are turned about, and with the feathers the Cylinder, or reed, but the Cylinder, or reed turns not the feathers as a certain Author supposes, to wit, the right motion of the reed is not retarded immediately, but the right motion of the Feathers, which because they are light, have not sufficient Impetus to overcome the resistance of the air, but mediately and consequently the right motion of the reed is retarded, and determin'd to the motion about the Axis from the like motion of the feathers; hence if by chance the feathers fall off from the Cylinder in the way, the Cylinder or reed makes a certain longer space, because it hath not the impediment of the right motion from the feathers, but as yet 'tis turned about its proper axis for some little time by the circular Impetus preconcieved, which is not presently destroyed.

Secondly,

Secondly, 'tis turned about the axis to that part, to which the feathers ſuffer the leaſt reſiſtance of air, for if the air ſhould equally reſiſt all, there is no reaſon why they ſhould be turned rather in one part than another; hence they ought to be ſo fitted, that they may Strike the air unequally; which will be if they are ſeperated or divided unequally, and then the motion about the Axis will be Swifter.

Thirdly, one feather only will not do becauſe it hinders the motion but little, neither is there in it an unequal reſiſtance of the air, of which I ſpake; wherefore there are required two feathers at leaſt, but three are better, becauſe they leſs hinder the turning about the Axis.

Fourthly, if the feathers are not ſeperated, the reed is turned about the Axis little or nothing, becauſe the air reſiſts them but little; but if they are much ſeperated, 'tis moved ſlower by the right motion, or Axis, but ſwifter by the motion about the Axis; notwithſtanding if they are too much ſeperated, the motion alſo about the Axis is ſlower, becauſe too much reſiſtance of air retards or hinders each motion; wherefore the feathers ought to be ſo fitted, that they do not impel the air with their whole ſuperficies,but divide it by the edge as it were to cut it.

Fifthly, if the feathers are fitted in a right manner that they be neither too much ſeperated, nor too cloſe, but a little bowed, with a moderate and unequal reſiſtance of air which their edges divide; then the motion of the reed about the Axis is not only ſwifter, but alſo the reed is projected further, becauſe the feathers are more eaſily broke off from the reed, and a little reſiſtance of air with ſome inequality ſuffices to the motion of turning about the axis, ſince this motion is eaſy.

Sixthly, It aſcends ſwifter while 'tis extended, than it deſcends afterwards, as appears clearly; from whence that is confirmed which we have ſhewn before, that heavy things naturally deſcending do not increaſe with the ſame kind of velocity, whereby the velocity of the ſame things caſt or thrown, decreaſes while they aſcend, and although both in the aſcent and deſcent, the reed, or cylinder, goes before the motion of the Feather; hence while it aſcends, becauſe the *Impetus* in the beginning is greater of the Feathers, which are flexible while they ſuffer the reſiſtance of the Air, they contract themſelves, whence it comes to paſs that they cut the Air the eaſier, and

therefore the reed aſcends the ſwifter, but 'tis leſs ſwiftly turn'd about the Axis; but while it deſcends, becauſe it acquires a leſſer *Impetus*, the Feathers make a greater ſpreading that it may move oftner about the Axis.

Seventhly, If the Reed be lighter, it cannot contain ſo much *Impetus*, which eaſily overcomes the reſiſtance of the Feathers; wherefore that it may hold out at length, ſo much *impetus* is required, that the Feathers cannot draw themſelves, unleſs from a great reſiſtance of Air they happen to be very much contracted, which while they are, it cannot be moved about the Axis.

Eightly, If it be longer, 'tis harder turn'd round the Axis, becauſe it eaſily ſhakes to and again; but the Feathers cannot together hinder the ſhaking, and impreſs the circular *impetus* to the Reed ſhaking.

Ninthly, If the Feathers are longer than needful, they hinder the right motion, or if they are likewiſe too broad, or too much ſeparated, or if they are too ſhort, and much contracted, they are not determined to motion about the Axis, for the reaſons aſſigned; wherefore care muſt be taken, as well to the length as the breadth, and ſeparation reſpectively to each other between themſelves, and to the gravity, or levity, length, or ſhortneſs of the Reed, or Cylinder.

Tenthly and *Laſtly*, the motion of the bearing, and about the Axis is mixt of a triple motion, one whereof is from the violent *Impetus* while it aſcends, another from the gravity, and the third from *impetus* by reflected motion, ſucceſſively by divers tangents whereby the circular motion is effected; and from all theſe motions, reſults the ſpiral motion as is manifeſt, and a ſpire is conceived about a crooked Cylinder, which poſſeſſes the whole place of air, or the way which the Reed ſucceſſively Occupies.

Hence 'tis eaſy from what has been ſaid, to determine the lines which are deſcribed by each point of the Reed, and alſo of the Feathers; in which alſo ſome trembling motion always intervenes.

Alſo a reaſon appears of the motion of the double ſtaff covered with the veil, which is turn'd about circularly, while in the interim 'tis conveyed by a right motion Horizontally by boys, as they run; alſo that motion is manifeſt to be ſpiral, which hath Spires more thick and cloſe, in which 'tis moved

more

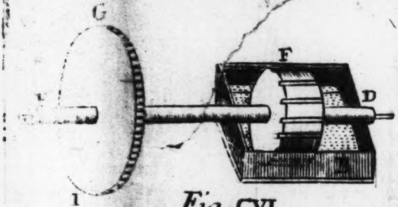


Fig. CVI.

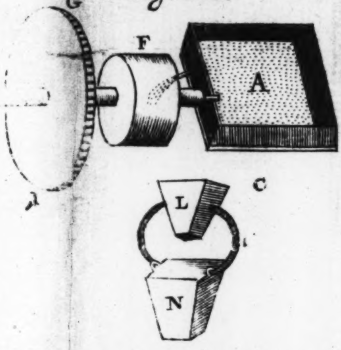


Fig. CVIII.

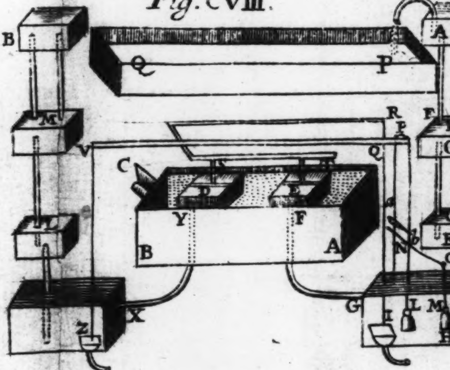
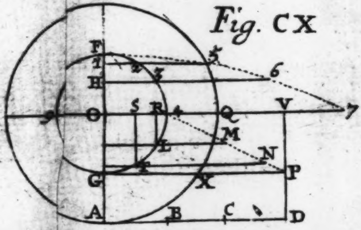


Fig. CX



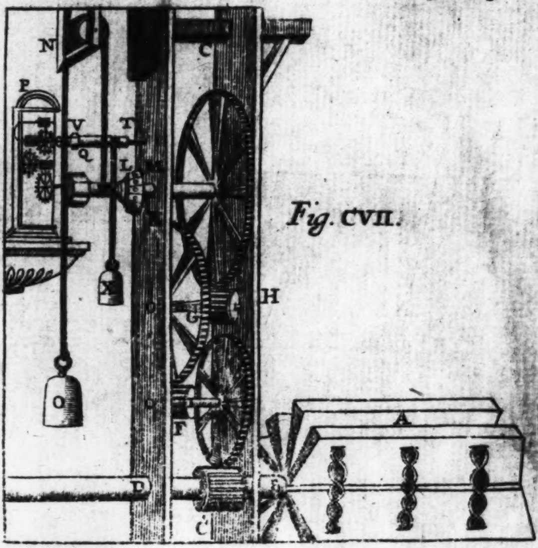


Fig. CVII.

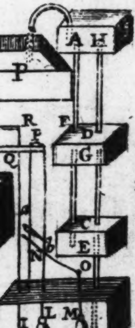


Fig. CIX.

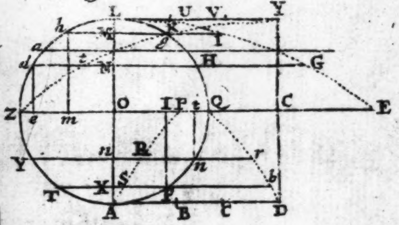


Fig. CXI.

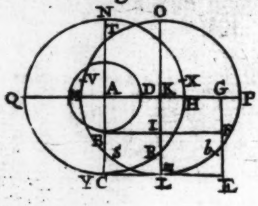
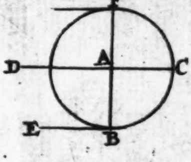


Fig. CXII.



more swift about the Centre, and slower by the motion of the Centre.

PROPOS. VII.

A reason may be given why a little Wheel, or little Globe, being prest against a Table, is first thrust forwards, but afterwards turns it self back again upon the Table.

THe reason is, because while 'tis strongly prest again the Table under it, this resists that in the point of contact, and while at once the *Impetus* is imprest forward by the retraction of the Finger, new contacts are made in other points often times, that therefore it conceives a circular motion contrary to that whereby 'tis moved, if the *Impetus* be only imprest forwards Horizontally; hence 'tis, that while it runs forward, at the same time 'tis moved circularly about the Centre, by the motion of rotation back again, *viz.* towards the Finger; and because that circular *impetus* continues longer than a right one, this ceasing, the other continues and compleats its effect, and so the Globe turns back again; for it cannot be turn'd about its centre, while it rests upon the Table, unless at once it be moved with a right motion of the centre towards the same part by the resistance of the Table in the point of contact, where you see this motion truly to proceed from some reflection; for the *impetus* imprest backward after that, is so weak (for 'tis weakned from the resistance of the plane Table) that it cannot overcome the resistance which is in the point of contact, from the Tables resisting 'tis somewhat reflected, and when the circular *impetus* continues, whose effect is easily obtained, neither can it be obtain'd but that it must role back again, therefore 'tis no wonder that it retroceeds.

Therefore 'tis false, that any *impetus* can persevere without the motion which exacts it, as Father *Cabens* would have it; for a little Globe, or little Wheel, is always moved with a circular motion about its centre towards the extrudent, in the same time wherein the motion of the centre tends forwards; yea, I have observed diligently, that if sometimes one touch a Globe while it runs forwards, it will not role about its proper

per centre, but creep upon the Table, which it always toucheth in the same point, then the Globe reflects not, nor goes back.

And 'tis to be observed, that while the Globe tends forwards, the motion about the centre is weak and slow, to wit, because the right motion upon the Table in a manner resists the contact, for it drives out the motion about the centre into the opposite part, to wit, forward; but the *impetus* ceasing, whereby 'twas moved forward, the impediment of the motion about the centre ceases, yea, it acquires a new determination to this motion, to wit, from the reflection of the planes resistance.

This reason assigned by us, appears not only from this, that, as I said, the Globe is not rolled back again, unless it be rolled about the centre also, in the same time which it runs forward; but also from this following experiment.

Experiment III.

Fig. 113. Grasp the Globe A, so with your Fingers about the Pole A, and the other opposite to it, that you may imprint the circular *impetus* about those Poles, or about the Axis whereby 'tis moved from E through H to G; and at the same time, cast the Globe through the Air, so that it goes by the line E F C, and falls upon the Horizontal plane in B, if that motion about the Axis be swift enough, either it will stay in the point of contact B, and yet it will be turn'd about for sometime upon the Axis from C through D in B, or also many times 'tis reverted from B towards G upon the plane; where it appears, in so much as the Globe is determin'd to the motion of rolling back again upon the Table, or Pavement, after that 'tis cast or thrown forward through the Air, in so much

Fig. 114. also it hath the motion about the Centre, while it is borne through the Air; for from this it is that the *impetus* being destroyed, by which it tends forward, while the Globe falls on the pavement, 'tis necessarily from thence reflected back again. For the Globe projected in the Air, proceeds by the line A B C D, and in the mean while is turned from B towards C D about the Centre C, while it touches the Pavement E D in D, according to the laws of reflexion it ought to reflect in F, and preceeding further to the same part

with ſo much impetus as D I; but if that impetus be ſmal (even as 'tis when the line C D comes near to the perpendicular C L) and the impetus whereby 'tis moved about the Centre be pretty ſtrong, this prevails over that, and while it perſeveres the Globe muſt needs role towards E upon the Pavement; hence it does not always go back, but only then when the motion about the Centre is ſwift, and it falls upon the pavement by a line which approaches more to a perpendicular.

PROPOS. VIII.

The motion of a Rope, or of a Ball, or Globe, faſtned to the end of a Rope about a Cylinder, is a Spiral motion compounded of many Circular.

S*Piral motion* is divided into many kinds, one whereof is when the motion is made about the ſame Cylinder, ſo that the circles are always equal, and this is mixt of circular only and right: Such as we ſaid was the motion of the reed, or Cylinder, furniſht with feathers; and of the double ſtaff provided with a veil, *&c.* and there is another Spiral motion alſo, which is made about the ſame firm centre, but by circles or wreaths enlarged or leſſened ſucceſſively more and more, or departing from, or approaching to the ſame centre; moreover there is another Spiral motion, in which the wreaths are not only enlarged or leſſened ſucceſſively, but they likewiſe retire from the former centre, to wit, it always changes the centre, and this is mixt of many circular, and of the right motion of the centre; but the ſecond kind of Spiral motion is mixt of leſſer circles only ſucceſſively; the firſt ſpiral motion is ſhewn by the figure A B, the ſecond by the figure C D, the third by the figure E F. *Fig.* 115.

Theſe things being fore-known, if we conſider the motion of a rope about a Cylinder, whether the rope be turn'd about by the Cylinder by circles, having divers centres in divers points of the Axis of the Cylinder, if it be, 'tis a ſpiral motion of the firſt kind; but if the motion of any determinate point in the rope be conſider'd, as for example, the end of the Rope

or

or the Globe annext to the end of it, then either it may so be turned about by the Cylinder, that the same centre always remains in the same point of the Axis, and then it appears, that since the radius is shortned successively, from that Globe is made a spiral motion of the second kind, which is compounded of circular motion only, for there may be perceived so many circular motions, although not perfect, as there are wreaths, or rather so many new determinations to new circular motion, as there are conceived *Radius*'s one successively shorter than another; or, it may be so turn'd about by the Cylinder, that the centre is changed at once, and then the motion of the Globe, or the end of the Rope, will be a spiral motion of the third kind, such as may be conceived to be made about the Cone E F, from F in E, which appears to be mixt from a right motion of the centre, through the Axis of the Cone, or Cylinder, and of many circular ones intelligible by Sence; for it cannot truly be said, that there are many circular motions, since none makes a perfect circle, yea, no part of that spiral line is part of a circular line, but if it be taken as a small part, 'tis a right line from what hath been said before; if as a compounded part, it consists of many right lines, *viz.* of many Tangents, yet not of the same circle, but of divers circles as appears.

Hence 'tis, that if a Cylinder be thicker, and a Rope of the same length being put on it, 'tis easier and with less imprinted *impetus* turn'd about by the Cylinder; to wit, because the parts of the circumference of the Cylinder are those which resist by impulse by a right line imprest in the beginning, and by the impediment, or a certain reflection, they determine to new and new lines oftentimes; and by how much greater the circumference is, by so much the less frequent is that new determination, as appears from what has been said; and so the lesser *impetus* is destroyed, as that which is moved by a greater circle is less wearied or tyred.

Secondly, It appears why a Globe doth not ascend, nor is turn'd about by a Cylinder, if the *impetus* be too weak in proportion to the thickness of the Cylinder, or to the length of the Rope; for although it be so great that a right line could ascend to that height, yet while it often suffers resistance by reflections and new determinations, 'tis much abated.

Thirdly,

Thirdly, if it be once turn'd about, it effects all the rest of the turnings about easily, because the circles are successively lessened, and so the motion is always lesser, when notwithstanding the former impetus perseveres almost the whole time: For if once the imprinted impetus decreases less than the wreaths decrease, one of the greater wreaths being finisht, the other lesser are also easily and therefore swifter accomplisht, and the velocity is increased proportionally to the lessening of the wreaths, not absolutely but comparatively to the remaining impetus, since also here, as is said, 'tis decreased or lessened successively, notwithstanding less than the wreaths; for if the wreaths and the impetus were lessened equally, the motion would not be quickned.

PROPOS. IX. *Fig.* 116.

If a Globe, or Wheel, be moved and turned about on a crooked superficies which is immoveable, it makes a mixt motion from a double circular.

LEt the crooked superficies be A BC, upon which the Globe B D is turned towards C; while the point E comes to F, the Centre of the Globe H comes to G. For the Centre alone is moved only by a circular motion through the arch H G I; but all the other points of the Globe are moved circularly by the motion of the Centre, and in like manner also by a circular motion about the proper centre, or axis.

But 'tis to be observed, that this mixt motion may be consider'd divers ways, for the crooked superficies on which the Globe is roled is either convex, or concave; and again, the Globe is turned either on a greater circle, or a lesser, or an equal; if notwithstanding the Concave be equal or lesser, the Globe, or Wheel, cannot be moved, as appears.

Moreover, observe that the Globe B D, whether it be less, or equal, or greater, than the Wheel, or crooked Superficies, on which 'tis moved, may be so moved that the Line of the moveable Globe B E, which successively touches the Circle A B C is equal to the Line BF, when the point E comes to F; or it may so be moved that the line B E is lesser, or lastly, so that it be greater than BF.

Thirdly, the foresaid Globe may be understood to move by the motion of the Centre towards C, and in like manner by the motion of the orb towards A, to wit, so that the point B tends to E and D, *&c.* and in each case the motion of the Centre may be equal to the motion of the orb, or greater, or lesser.

Fourthly, Note, that if *Copernicus* his opinion be true, that the earth is moved with this mixt motion, to wit, by the motion of Centre through a circle of the greater orb about the Sun, and by the motion of the orb about the proper Centre; and the motion of the Centre should be greater than the motion of the orb, according to the common opinion concerning the Diameter of the great orb, which the earth runs through in one whole year: Where also observe, that every point of the same parallel Circle are moved with unequal velocity; for whether we suppose the motion of the orb and the motion of the Centre to be towards the same part, suppose towards C, when the point E comes to F, and the Centre H in G, the point B will be in E, and the point D will be in L, wherefore the point of Contact B is moved slowest of all, but the opposite point D swiftest of all; that answers to the Nocturnal meridian, this to the Diurnal meridian. Or whether we suppose the earth to be moved by the motion of the Centre towards C, and the motion of the orb from B in E, D, *&c.* in this case the contrary happens, to wit, the point of Contact B is moved swiftest of all, for it comes to L, and the point D slowest, for it comes to E; and these kinds of motion of divers points of the same circle will be slower, or swifter, according to the divers proportions of velocity of the motion of the Centre, and the motion of the orb, nevertheless all will be by crooked lines, as appears by what has been said.

Fifthly, after this last manner, some Epicicles are said to move by Astronomers, to wit, by the motion of the Centre to the East, according to the Series of the Signs, or, as they say, in the Consequent; suppose the Centre C towards A, and the Supream point, or the Planets *Apogæum* D, moved in the opposite part from D in E towards the west, and, as they say, in the Antecedent.

But since the foresaid motion may be divers according to the divers magnitudes, and proportions of the Circles, it appears nevertheless from the doctrine deliver'd before, that the lines

lines of all the points deſcribed by the motion of any circle, may be determin'd howſo'ver 'tis moved on one or another, which may be of great uſe in Aſtronomy.

PROPOS. X.

The Spiral motion of Sphæres may be explicated, to wit, when a Sphære is moved by a motion mixt of Right and Circular, or of two Circular ones.

Fig. 117. FOr in the firſt place, let the Sphære BC be moved by its centre A through the right line AH, and at the ſame time turn it about the axis BC; moreover every point, except the Poles B, C, deſcribes Spiral lines, as if they were Spires, or wreaths, about divers Cylinders, about the greater Cylinder, truly the ſpire which it deſcribes is from the point F or G, but about the leſſer, which is deſcribed from the point, next to the Pole C or B. But if it be turned about the Axis FG, or any other oblique, it will be another divers mixt motion in divers points, whoſe lines may eaſily be found by the foreſaid doctrine.

In the ſecond place, let the point G be moved through the arch GC, and at the ſame time underſtand it to move about the Axis BC, it will be a Sphærical Spiral motion mixt of a double circular.

Thirdly, let the ſame point G be moved through the right light line GC, while 'tis moved alſo about the Axis BC; the motion will be conicaly Spiral, mixt of Right and Circular.

Beſides the *Sphæric Spiral motion*, there may be made another motion *Conoid Spiral*, to wit, if a *Conoid* be turn'd about one, or about the other Axis, while its point is ſomewhat moved through a right line; and 'tis of a threefold kind, *viz.* either *Elliptic*, or *Parabolic*, or *Hyberbolic*, as appears by *Geometry*, and from the *Mechanick* deſcription of thoſe figures.

PROPOS. XI.

In the motion of a globe upon a plane, a three-fold motion may conjoined, so that it may be mixt of a Right and two Circular ones.

THis experiment appears from the game at Billiards in players balls, for while the Centre is moved through a right line. and the other points about the Centre, suppose in a vertical circle, if the globe either by oblique reflexion, or by a new impulse, be never so little turn'd aside about the Horizontal, or other line, it concieves another circular motion also by that line, and so besides the right motion of the Centre there is a double circular. And from this appears the reason of the said plays; as for example, while the ball is moved by the right motion of the Centre, and by the circular motion of the orb together, if the Chord be toucht lightly 'tis turned a little a side and makes another circular motion, from whence it follows afterwards, that the leap decieves the player, because the new circular motion acquires a new determination in the reflection, *&c.*

PROPOS. XII.

A Globe, or such like body, insisting on a plane cannot move circularly about the Penpendicular Axis, unless at the same time it be imprinted by a double impetus in opposite parts. Fig. 118.

LEt the Globe, or Top, such as children play with of a Conoid figure be A B, resting on a plane in the point B, and you would have it move about the axis A B in an Horizontal circle C D: I say, it cannot so move, unless all under one it be imprest; or forced by a double opposite impetus, one, for example, in C towards the right hand, and the other in D towards the left hand part; the reason is, because if it be forced by one impetus

impetus only it will be determined to one only right line, and ſince there is no impediment ſuppoſed, which may hinder the Globe that it ſhould not be moved by that line, it will be moved by it, and ſo be turned on the plane in the vertical circle A C D B, but the top will fall to that part towards which the impetus is impreſt. But if at the ſame time another impetus be impreſt on the oppoſite part, when theſe two impetus's are not by the ſame line, but by two divers lines parallel to each other, either may have its effect by chance, and when one at once hath the reaſon of the impediment with reſpect to the other, leaſt the Globe, or top, proſecute the motion by right lines, 'tis determined to circular motion, for neither can thoſe two impetus's obtain their effects any other way; hence it is, that the top being taken by the head, or its end of the Axis A, and being caſt off by the fingers in contrary parts we make it Spin, or turn in circuits; and it perſeveres this circular motion a long time, becauſe the impetus is not deſtroyed by the weight ſince the top is in *Equilibrio*, but the only by rubbing with the plane, and from ſome reſiſtance which every moment changes the determination of the tangent lines; hence the ſmoother the plane is, and the ſharper the point of the top is, the longer time it ſpins, or proſecutes the motion.

But when we wind a ſtring about the top, and retain the other end of it in the hand, and caſting it from us it ſpins, then in like manner that double impetus happens in the oppoſite parts; for not only while the ſtring D E unfolds, doth it draw towards us the point D, but at the ſame time with the ſame ſtring we throw the top from us like a ſling; and the motion of the top endures longer being caſt in this manner, by ſo much as the impetus's are greater and the ſtring the longer, becauſe a power applied remains longer, and while the projected impetus perſeveres the other impetus of the ſtring being retracted in the oppoſite part, and hindering the former impetus, gives many new determinations to new and new tangents.

While the top is caſt, it makes a motion mixt from the right motion of the centre, and of the Horizontal circular, as appears, or alſo of another right motion which tends downwards.

Secondly, when it inſiſts on a plane, if the ſame point on which it inſiſts be moved only by a circular motion about the axis, then 'tis ſaid to ſleep, yet in truth the motion of the Axis is

but

but little moved about the Centre of gravity which is in the Axis; but becauſe it either finds it on the plane, or makes hollow ſome little trench of it ſelf, this trench detains the Axis, leaſt it ſhould go out of it, unleſs afterwards the Axis begins to incline more.

Thirdly, thereupon it moves always by a motion mixt of a circular about the Axis, and of a circular of the ends of the Axis, ſo that alſo if any point of the Axis remain immoveable, yet the extream points of the Axis deſcribe two circles, one in the plane, the other in the air above.

Fourthly, ſometimes another motion of the whole Axis happens to the foreſaid motions, which is carried about not in a perfect orb, but ſpirally, the Spires, or wreaths, ſucceſſively more and more contracting untill it begins to ſleep; and this motion is always on that part to which the outer portion of the top by its motion is turned about the Axis; to wit, becauſe this Spiral motion of the Axis is determined from the circular motion about the Axis; you ſee therefore many motions in a top, one about its Axis in an Horizontal circle, another of the ſame Axis, and the Spiral of the Centre; laſtly, another of the turning round of its Axis about ſome of its points, by which motion of turning or trembling the foreſaid little circles are deſcribed by the top and point of the Axis.

But the Impetus of the orb about the Axis ceaſing after that, and the turning about and the inclination of the Axis prevailing, the Centre of gravity ſo departs from the line of direction, that the Impetus of the orb cannot keep the Axis erect, the top falls; and then becauſe in it there remains as yet much of the former impetus, it makes ſtill ſome oblique turnings or Circuits, which although they ſeem to be made in the oppoſite part, yet they are made (if you attend rightly) on the ſame part on which the circular motion about the Axis was made; which when 'tis hindred by the contact of the Plane, therefore afterwards 'tis rolled about upon the Plane, and now is more moved by the motion of the Centre which before was hindred by motion of the orb, or that from this you may know the nature to be loved of the right motion of the Centre, but not of the orb about the Centre.

Mechanick

Mechanick Powers.

Of Circular Motion artificially fitted to Mechanick use.

BOOK. IX.

YOU ſhall ſcarce ſee any ingenious Engin in which either circular motion doth not appear, or at leaſt that which may not be reduced thereto, notwithſtanding in this place we ſhall treat only of thoſe kinds of Engins, or Inventions, which immediately depend on the Principles, and Doctrine of Circular motion hinted at before.

Problem. I.

To make divers kinds of Wheels commonly uſed in Engins.

GEnerally we make uſe of two ſorts of Wheels, one whereof is furniſht with teeth, and the other hath none; thoſe that have none are ſingle Wheels, and Pulleys, which are hollowed in the Periphery for the Rope to move in, as alſo Wheels with handles to turn them by: And the firſt ſort of Wheels contains as many kinds, as there are various forms of teeth, which I think fit to deſcribe in the firſt place, for the better underſtanding of what follows, and that any one may know how to make choice of thoſe kind of Wheels which he eſteems moſt fit for his occaſion.

Teeth, or,as ſome call them, *Claws*, or handles turning round, their chief uſe about Wheels is, that they lay hold on, or bite each other, and being folded in each other they cauſe a reci-

procal motion, and they are various as you may ſee in *Fig.* 119. from whence the names of thoſe wheels are divers.

A toothed Wheel is, that whoſe Periphery ſticks out with little handles endued with *Semicylidric* form, as in the arch A F, or a plain ſided Priſme, as in the arch E F.

A Fingered Wheel is, that whoſe Periphery is garniſht with plain Cylindrick ſmall ſtakes, as in the arch A B, or ſomewhat like Cylinders, as in the arch B C.

A ſharp pointed Wheel is,that whoſe Periphery is cut in with little handles turning round like the figure of a point of a Sword, or of a tongue,as in the arch E D may be ſeen.

A Studded Wheel is, that in whoſe Periphery little Sphæres, or Convex Hemiſphæres are diſpoſed, or the Concaves are made hollow anſwering to the Convexes in the other Wheel, the firſt parcel referrs to the arch C D.

A Starred Wheel, is that whoſe Circumference is furniſht with three ſided Priſmes having each ſide equal, as in the arch G H.

A Snagged, or ſawed Wheel, is the ſame as the former, only with this difference in the former, the triangular ſides of the Priſme are equal, but in this they are unequal, as in the arch G N.

A helical, or ſcrew Wheel is, that in whoſe circumference chanellings or grooves are made, according to the quantity of the angle of the Axis of the inclined wheel, whatſoever figure the ſame hath, which nevertheleſs are reduced to four kinds, *Semicylindric*, as in the arch A F, *Trigonal*, as in the arch G H, of four ſides, as in the arch K L, *Trapezias*, or unequal 4 ſides, as M L.

A hooked, or crooked Wheel, is that which hath hooks diſpoſed in its circumference, as in the arches H K, and N M, you may behold.

Alſo Wheels are named with reſpect to the figure of their Wheels, let the teeth be what they will; for, ſome are called plain Wheels, or *Orbiculates*, in which the baſes of the *Cogs* or *Teeth* are all in the ſame plane; others are called *Convex Cylindric*, when the *Cogs* are diſpoſed in the outer ſuperficies of the *Cylinder*, or any circle thereof: Others are called *Concave Cylindric*, in whoſe inner *Cylindric* ſuperficies the ſame *Cogs* are diſpoſed: In like manner ſome Wheels are called *Convex Conic*, others *Concave Conic*, even as is ſaid of *Cylindric*: Laſtly, a Wheel

a Wheel without teeth, and whoſe Periphery hath nothing ſticking out, they call ſmooth or even.

Note, that all the kinds of teeth, or Cogs deſcribed, or any other ſuch like, may be made, not only in the Periphery, or outermoſt ſuperficie of the Wheel, but alſo in one or both of the lateral ſuperficies, or Circular, or Cylindric baſes.

Problem. II.

To apply Weights, or Powers (moving by their natural gravity) to Clocks, or other Engins.

ALmoſt all kind of Engins, which are moved by inanimate Power, are uſually made with ſome Wheel, or Cylinder, to which a weight being hung, while it endeavours downwards by its natural gravity, it moves that Wheel, or Cylinder, and that puts the other parts of the Engin in motion, as appears in common Wheel Clocks: And weights may be applied to Wheels many ways, which we will unfold, before we proceed to the making of the Engins: The firſt way of hanging weights to common Clocks, or other Wheels, which by ſome determinate time, being placed in the middle and impelling, ought to turn them round, is, that one end of the Chord, or Rope, be fixt to the Cylindric Axis of the Wheel, and the other end ſufficiently faſtned to the weight, as you may precieve in the Figure: And in this practiſe you *Fig.* 120. muſt beware, that the Cylinder be not wanting to the rope, for it ought to have only ſo much length, that the whole Chord may be turned about it, for if the rope be twice wound about the ſame Cylinder, that is, if the latter windings of the Rope fall upon the former, it will come to paſs that the formoſt motion (*viz.* while that part of the Rope deſcends which is wound about the other) the motion will be ſwifter than that of the latter, to wit, while the remaining part of the Rope deſcends which is immediately wound about the Cylinder.

The ſecond way is, when weights are hung to each end of the Rope, as appears in the Figure: For the Rope ABC is put upon the Pully D, in whoſe Periphe- *Fig.* 121. ry there is a hollowing, or groove cut arching, ſo that the Rope may lie in it, and recieve firmly in it the draw-

ing force of the weight, and the weight A must not descend without turning the Pulley about, and consequently raises the weight C.

In practicing this Artificers are commonly mistaken, for some in the foresaid hollowing of the Pulley D, make 6 or 8 sharp points sticking out to hinder, least the Rope being drawn by the force of the weight A should not turn about the Pulley.

But those sharp points render the motion of the Pulley, and so of the Clock, or other engin, altogether unequal; others make the Cavity or hollowing of the Pulley narrower in one place, and wider in another, from whence it follows, that the Rope being unequally distant from the Centre makes the motion unequal.

Therefore if the Rope slips without turning the Pulley those sharp points may be used, but a greater number must be affixt, and they ought to stand out all alike, and equal upon the Periphery of the little Wheel; which may be performed more safely if you glew on some little balls like button moulds or beads to the whole Chord, or fix them in some other manner which may be all alike and equally distant to each other; and in the Cavity, or hollowing of the Periphery of the Pulley, make little holes or cavities right with the same distances, which Cavities must answer the little buttons or beads, and receive them within them one after another: Some instead of these, tye knots in the rope, being equally distant.

Fig. 122. The third manner in use is, when the space for the descent of the weight is too low, or short, or of too few hours; or if it be sufficient, we would notwithstanding extend the motion of the clock, or dial, to more hours. For then we double the Rope, which may again be done in a twofold manner; first, one end of the Rope is fast bound to some place A, and the other end to the Axis, or Cylinder E, of the Wheel, which it ought to go about; as for example in D, this Rope A B D sustains the little Pulley C with the weight annext to it, and this whole weight together with the little Pulley C ought to be double of that which is hanged to the single Rope; also the Rope may be triplicated, quadruplicated, *&c.* *Fig.* 123. if there be added above and beneath other Pulleys, in which case also the weight may be in like manner triplicated or quadruplicated, *&c.* In the second place by the

the double Pulley D, C, one of which being annext to the weight C, and the other to the Counterpoise D, and the ends of the Rope B and E are fastned to some firm immovable place; so while the weight descends with the Pulley C, it turns the Wheel, or Pulley A, and lifts up the counterpoise D.

Fig. 124. The fourth manner is by a continual Rope, disposed in such manner as the figure shews, in which A is the lowest Wheel of the Clock, or such like Engin, or the pulley annext to the Wheel, and made hollow in the Periphery to recieve the Rope firmly, as we have said before. B is another Pulley like to the former, and moreover furnisht with saw-like teeth, and with a pin C so fastned to the side that it endeavours against the teeth while the weight D descends, that the Pulley B be not turned about at that time; but the Pulley A is roled about and lifts up leisurely the counterpoise or weight E annext to the pulley; where you see there is no extream head of the Rope, but it is one continued Rope, and put into the Pullies, whence 'tis called perpetual or infinite. When therefore the weight D descends to the lower part, and the weight E is carried to the upper part, the Rope being taken by the hand in F, and by drawing downwards raises the weight D again and depresses the weight E, for the pin C endeavours not against the motion of the Pulley B, but alone against the opposite motion.

The peculiar conveniency of this Rope, and the application or disposition of the weight consists in this, that in the same space of time, wherein the Rope is drawn, and the weight raised to continue the motion of the Clock, the motion of the clock is not interrupted, as happens in others; for also while 'tis drawn upwards by drawing of the Chord in F, it discharges its office in enforcing the Pulley A, which truly is of great moment to the exact perfection of Clocks, and such like Engins, and the knowledge of time.

Fig. 125.

Likewise you see by this doubling of the Rope, that the slowness of the weight's descent is doubled to that it would have by a single Rope; and it might, if need were, be quadruplicated, and be made greater than any given proportion. You may add to the two pulleys A, B, another Pulley G, and to the Pulley D adjoin another little Wheel about the same Axis, or if divers, join it at least with the other Axis. Then this perpe-

tual Rope being drawn about all the Pulleys, *viz.* A D G D B E A; for ſo the deſcent of the weight D will be four fold ſlower, and therefore the weight ought to be four fold greater, yea, and ſomewhat more, becauſe of the much rubing of the Pulleys with the Rope, and the reſiſtance, *&c.*

Fig. 126. The fifth manner is this, the Pulley B is underſtood to be firmly affixed to the lower Wheel of the Clock, the other A ſtabliſhed ſomewhere commodiouſly, and being furniſht with ſaw-like teeth with an Iron Pin to endeavour againſt the weight, as is ſaid before; from the perpetual chords of theſe Pulleys hangs the weight H in the little concentric Pulleys E F G and C D N, one of which is conjoyned immovably to the other, and both together about the common axis of that which turns eaſily: Moreover below let there be two Pulleys K and L conjoined in their centers to the common beam K L, in the middle whereof hang. the weight M. About theſe and the former Pulleys draw two perpetual chords by this artifice, the firſt Chord is B L G F E G B, to wit, ſo that it fold about the Periphery, or circuit of the whole Pulley E F G once: The other Chord in like manner, muſt be drawn about the whole Periphery, of the leſſer Pulley C D N, concentric with the former, ſo that this whole Chord be A C N D C K A. But now that which is ſaid concerning this laſt Chord, and the pulleys belonging to it, is, that it ought to be done altogether like to the other, but placed on the other face or ſide of the Pulleys, which in like manner contains a certain leſſer Pully equal to C D N, ſtanding out on the other part and divides the whole office of holding or bearing up with the other; wherefore it behoves the Pulleys A and K to be alike.

That therefore the weight H be drawn with its Pulleys on which it hangs, you muſt apprehend the Chord A K, either alone or compared with another, *viz.* in E, and drawn downwards; for ſo it comes to paſs that the weight H aſcends, yet in the mean while the motion of the Pulley B is not ſtopt, and conſequently neither the motion of the Clock, or other Engin: So likewiſe it appears in this method, as alſo in the precedent, that the attraction of the weight may be continued as long as you pleaſe without hindering the motion of the Engin. Laſtly, it appears in this laſt method that the motion downward of the weight may be made ſlow according to any given proportion,

tion, to wit, in that proportion which the diameters of the Concentric pulleys CDN and GEF have to each other; and in the same proportion the weight will always be increast.

Problem. III.

To appply a Sphærical, or rolling weight, to the Wheels of Clocks, or other Engins, by finite Chords, as well as by infinite Chords,

Since oftentimes it is necessary in the artificial construction of Clocks, and other Engins, to make use of Sphærical or rolling weights, two or more whereof succeed each other mutually to continue or perpetuate the motion of the Engin, as will appear by what shall be said; therefore we will deliver a double method, whereby it may easily be obtain'd.

Fig. 127. First, it may be done by a perpetual Chord, or Thong of Leather twisted; for let there be two Pulleys, or short Cylinders A and B, A being fixt to the lowest Wheel of the Clock, and B stablisht in the lowest place to which the weight ought to descend; put on each the perpetual chord ABCDA, or a Thong made of the Hide of a Beast; then take another Thong altogether like to the former and put about the same Cylinders, or on two other pulleys parallel to the former and distant from them so much as is the diameter of the Sphærical weight D, which is sufficient to turn the clock or Engin, this interval of the double Thong being observed, joyn one Thong with the other by ranks of certain transverse Irons semicylindrical, whose bases are EHI, LMN: And they are easily connected if you drive a Nail through each Semicylinder, and the Thong which folds about it, or if by chance the Thongs of the Semicylinders strain in the middle, it will make a Scale, as appears in the Figure PQ, so that the Sphæric weight D being placed between the foresaid degrees will be sustain'd by the lower pair of Cylinders, *viz.* in F. But that these kind of perpetual Scales may be turn'd about with the Cylinders A and B with an uniform motion, there must be made hollow Semicylindric grooves or Channelings in the Peripheries of the Cylinders, in which are received the convex Semicylinder of the Scale.

If the Sphæric weight D be of a great bulk, the Thongs may be made of double or triple Leather that they break not, or in stead of them Iron chains may be used. The

The chief uſe of this perpetual Scale is to continue the motion of the Clock, or other Engin; for after that the weight D is deſcended to the loweſt part G, 'tis caſt away by the Scale, which will be done either from the Pulley B, or better from ſome obſtacle fitted below for this purpoſe; then the Globe breaking out from the Scale in the lower groove G, lifting up ſome peſtle of Iron by means of a Thred or Chord, opens an entrance to the other Globe in the upper groove E, that it may ſucceed in his place on the top of the Scale; but the former Globe depoſed in G is lifted up again to the groove E, by an artifice which we will ſhew in the following *Problem*, that it may again deſcend by the Scale, *&c.*

Fig. 128. *Secondly*, it may be done thus, affix the Pulley H to the loweſt Wheel of the Engin, which ought to move and turn eaſily about its Axis, having in its Periphery Saw-like Teeth with the Peſtle R, which being fixt in ſome place of the Wheel, and fitted with a plate of metal preſſing; put the Rope L H K upon this Pulley, faſtning to one of its ends L ſome little Box or Basket wherein the Globe may be received, and to the other end K, hang a weight of ſuch gravity, that it may draw up the Basket free from the Globe, from the bottom Q to the top, where now it appears in the figure, which the Peſtle R will not hinder, which hinders only the oppoſite motion of the Pulley H, and that the Globe may be contain'd within the Box or Basket, and not ſlip out of it, erect two or more rules P Q and M N, *&c.* But after that the Box with the Globe is deſcended to the bottom Q S, the Globe muſt run out of the Box, either by mangling the rule N, or by the declivity of the bottom Q S; Laſtly, the Box or Basket being freed from the Globe, is lifted or raiſed upwards by the weight K, and being advanced to P M, takes in there the other Globe equal to the former, and that the Clock, or other engin, may be kept in motion while it is let down in Q, and raiſed again in M, we will ſhew by and by.

Problem. IV.

To convey weights, moving an Engin up to the upper part, after their descent to the lowest part.

Fig. 127. THis may be done many ways; first, by the perpetual Scale described in the preceeding Problem, for if you understand a Toothed Wheel joyned to the Pulley A, and firmly adhearing to the same Axis, if then this toothed Wheel be moved together with the Pulley A by any superstructure, or any other way from the power impelling the Supream Wheel, or part of the Engin, and the motion be made from A towards C, the Globe, or weight D, will be raised gently from the bottom to the top, whence it devolves again to animate the Clock, or other Engin, by the artifice explicated in the precedent Problem.

Secondly, the Artifice in the same third Problem, explicated in the second place may easily be applied to the drawing Sphærical weights, from the bottom to the upper most part. For let there be a toothed Wheel A B C to which there may be others made according as the thing requires; place the Pulley D E on the axis of this Wheel on which a Rope being put, let one end of it sustain the Sphærical weight P within its Box or Basket, and on the other end hang the Counterpoise N, a little lighter than the Basket P without the Globe, or weight, that from this that may be taken up. The Pestle B furnisht with a little wing lays hold on the Snags of the Pulley, and detains it against the endeavour of the weight P. Also make a certain dovetail D F in the Periphery of such bigness, that it may be equal to a quadrant of the Circle, or exceed it, in the middle of this make a long slit D F, through which the common axis D of the Wheel and of the Pulley may pass; moreover make a moving leaver H G F C made firm somewhere about the point G, with which Leaver the foresaid dovetail is linked in the point F: Then in the point A fix a spar, or bolt A K, furnisht with a pressing wing and movable about the point A, and near this bolt place a Leaver full of corners or nooks K L M N movable in the point M.

These things thus disposed, If by the motion of the Wheel A B C the weight be elevated leisurely to the top of its altitude, and

and being ſlipt from the Basket or Box into the groove or Channel leading it to the deſigned place for animation of the Clock, notwithſtanding the empty basket will be moved by the power raiſing it, untill it hits againſt the Leaver C G H and lifts it up a little, and the Leaver being raiſed takes up together with it the dovetail F D: And this Peſtle B being ſtretcht at length through the whole thickneſs of the Pulley in this part to the dovetail; in the mean while that the end H of the leaver C G H being depreſſed lays hold on the bolt A K and detains it, at the ſame time the Peſtle B being lifted up without the Snags of the Pulley, the basket P, although empty, yet heavier than the counterpoiſe, N will turn the Pulley, and it will deſcend to the bottom that there it may again receive another Sphærical weight to be drawn up in the ſame manner.

For the counterpoiſe either of it ſelf, or by making a certain knot in the Rope will raiſe the nooky Leaver N M L, and by it withdraw the bolt A K that it detain not any longer the end H, which being looſed, the dovetale D F falls off, and then the Peſtle B being ſent down lays hold on the Jags of the Pulley that the attraction of the weight may be made again.

If you fear leſt before the Peſtle B being drove away by the Snagged teeth of the Pulley, and the Pulley with the Basket ſhould begin to deſcend before the end H is laid hold on by the bolt A K; then hang ſo much weight to the arm G H of the Leaver as ſuffices to raiſe the dovetale with the Peſtle B; and that the weight be not raiſed ſooner than the basket aſcends upwards, detain this arm G H by a certain crook or hook made after the ſame manner as the hook N H in the following Figure. But then in ſtead of the arm F C, the arm M N will be produced, that that being raiſed from the basket will withdraw the hook ſuſtaining the endeavour downward of the end H which is heavieſt; Moreover it will reſtore it to its former ſite aſcending with the Impetus of the counterpoiſe N.

Alſo note, that when the Wheel A B C is often turn'd about in drawing of the weight, and conveys the Peſtle B every where with it ſelf, that when the attraction is finiſht, the Peſtle B will be found in the upper quadrant that is above the dovetale, which always certainly happens, if in the Rope or little chain of the Pulley you make little knots or buttons for

that

that purpoſe, according as 'tis ſhewn in the ſecond Problem.

Fig. 130. *Thirdly*, the ſame Pulley may be freed from its Peſtle by another artifice; let the ſame Wheel B ſtick faſt to the axis C, and the Pulley D movable thus, that it may be moved to and fro by the Axis A C; Then after that the Basket E is brought to its height, it will raiſe in the firſt place the knotty Leaver E F G fixt movably in F; and this by the little arm G H drives out the hook H N, whereby the other knotty Leaver M L K is ſuſtain'd, to whoſe arm L K ſo much weight muſt be hung as is convenient, that the other arm L M laying hold on the Tube M P, joyned to the hole of the Pulley D, may draw the Pulley by the Axis A C towards C, although againſt the ordinary reſiſtance of the force of the Hælix C P: And in this manner, thoſe jagged teeth of the Pulley are withdrawn from the Peſtle B, and the Basket E deſcends with its weight, by turning round the Pulley together freed from the obſtacle of the Peſtle; notwithſtanding in the mean while the little arm L M touches it highly, and detains the Tube ending in the rundle, in which the contact may be facilitated by adhibiting the little Wheel, or a turning Cylinder, *&c.*

The arrival of the Counterpoiſe will make the Pulley repair to its place, for this when the impetus of the knotty Leaver M L K, lifts up the end K, it places it in the hook H N; which being done the pulley is forc'd into its place, by the preſſing Hælix led about the Axis.

Hence alſo you muſt take care, in making the Peſtle B, that it be not let or bore down from its little wing, deeper than the inciſſions, or Jags of the Pulley.

Problem. IV.

To fit an irregular finite, and diſorderly moving power, ſo to an Engin, that it ſhall make a well order'd regular, or wholly equal motion.

SInce Regularity and equality appears in no other motion more than in the Circular, which of its own nature ſeems to require equality; we ſhall in this place declare thoſe things which are for obtaining this equality of motion, which truly are of great moment in Engins, eſpecially in the conſtruction of

 thoſe

those that measure time. And of these kind of Irregular powers some are perpetual, or infinite, and others finite which do execute their office to time. We shall treat of these last in this place, and of the former we shall say something hereafter; heavy things being hung at liberty whether hanging from an Engin, or some Wheel, are called regular powers, because whether they are hung high or low, they always obtain equal force or moment; notwithstanding if they are placed in some ambit of the same Wheel according to a divers site, and the same inclination, they acquire divers moments as appears from what has been said elsewhere; but 'tis needless to reduce this irregularity of weights to regularity, since that may easily be done.

Therefore irregular Powers which we commonly use in the construction and motion of Engins are Springs, that is, certain thin pieces of mettal in manner of an Hælix, or wrapt up in Spires such as are commonly used in watches, concerning which something is said before.

First, the resistance of the said thin pieces of mettal is less in the beginning while they are bent or drawn than in the end, and in like manner when they are drawn or bent have greater force, and make a greater endeavour to restore themselves into their first station in the beginning of restitution or reduction than in the end, and this force increases or decreases not uniformly, and with a proportional increase to the adductive or reductive motion, but with another certain increase or progression not as yet certainly known, of which in its place.

Secondly, if the thin piece of mettal be bowed or bent into a Spire, or larger Spieres, the bending resists less, and makes less force to reduce it self than if it be bent in lesser Spires; hence 'tis, that in this second case it hath greater force whereby it desires to restore it self, but obtains lesser motion.

Thirdly, Springs, or the same thin pieces of mettal being bowed into a Spire or wreath, may be drawn more violent either in the Centre, or in the Circumference, or in both parts together; if the thin plates consisting in the extream which is in the circumference, the plate will be drawn by the wresting of the other extream being in the Centre, it resists the drawing less than if remaining centrelly immovable in the extream, the plate be wreathed about in the Periphery, the reason is, because in this second case it ought not only to out go the resistance

ance of bending, but alſo the other of rubbing, or weaving of one volute upon the other, which reſiſtance nevertheleſs it hath by accident.

Fourthly, Springs are made weaker by degrees by often drawing them, but they are more weakned if they never reſtore themſelves, but if always, or for a long time, they continue drawn or pull'd; hence they have greater force in the firſt making of an Engin, but leſſer after long uſing them.

Fifthly, if they remain ſometime free, that is, without drawing, they recover ſome of their ſtrength which they had loſt before.

Sixthly, *Jo. Helmont* in his Book entituled *Med. Phyſic. de tempore*, *Num.* 50. affirms, That the ſaid Springs of Clocks or Watches are wont to be more ſtrong, or ſtubborn, when the North wind blows, which notwithſtanding is not as yet well known to me, neither doth the cauſe of this *Phænomena* eaſily appear, unleſs you'll ſay from *Cold*, which is wont to be more rigid when the Wind is Northward.

Theſe things being noted, the irregular force of Springs may be reduced to uniformity divers ways: Firſt, when theſe thin pieces of Mettal are wont to be made every where of the ſame breadth and thickneſs, they exert their force unequally in the beginning and in the end; if the parts near the Centre be made thicker than the other, or broader with a due proportion, and then the drawing to, or lapping up being made in the Centre, the reſiſtance will be equal and uniform in the whole drawing, or wreathing, and conſequently they will make the force equal in their whole reſtitution, until they come to their firſt ſtate, or condition; moreover on the contrary, if they are made thicker in the parts neareſt the circumference, and then the drawing be made in the circumference, from the oppoſite reaſon there will be an inequality of force to compenſate or amend that unequal thickneſs or breadth of the thin plate; notwithſtanding this way, whereby the inequality of this thickneſs compenſates, the inequality of force is not uſed, perhaps becauſe 'tis more laborious, and neither is it eaſy to find the proportion, whereby the thickneſs ought to be increaſed gradually; yet if it were reduced into practice, it would be far more uſeful and certain than the other.

The ſecond way more obvious, and uſed in regulating the Springs in ancient Watches, is, by an unequal preſſion of

the ſtrongeſt part of the Spring, and that is made in a certain changable Orb like the figure of an heart, for this Orb when the ſpiral plate makes leſs force, is alſo leſs preſſed from the other plate, or hindering wing; but when it exerts greater force in like manner that force is abated, ſo that 'tis reduced to a certain quality; alſo this way is ſcarcely uſed now among modern Artiſts, when notwithſtanding 'tis leſs laborious, and, as Experience teaches, oft-times more uſeful than others; perhaps 'tis deſpiſed becauſe 'tis more ſimple, to deter others from inquiring into an Art which is more ſubtil, which they would do, if it were eaſier and ſimple.

Fig. 131. The third way, which is at this time moſt in uſe is, a Hælyx of Steel included in the Cylinder A B C D, movable about the durable axis E F; this axis paſſes by the centre of the Hælix, and detains its central end firmly, and leſt it ſhould be turn'd about together with the Spire or Wreath and Cylinder, 'tis hindred by a jagged wheel G H, firmly put into an axis, and a little bolt or peſtle H I, which ſtrives againſt the Jags of the Wheel: To the ſide of the Cylinder a Cone is made, or ſome other ſuch body ſharpned at top like to a Top C K M, movable about the axis L M, the Periphery of this top is made in the manner of a Screw, with channellings or cavities made round it to receive a chord or chain, one end whereof is faſtned in the point of the Cone K, and wound about the Cylinder, the other end of the chord is faſtned to the Cylinder in D; theſe things thus conſtituted, the inequality of the reſiſtance of the ſteel ſpires, or wreaths, drawing irregularly is made fit or meet by the deformity of the top, which where the reſiſtance of the ſpire or wreath is leaſt, the greater Periphery being turn'd receives the chord, whereby the Cylinder is drawn about, carrying about the included end of the ſpire or wreath fixt to the Cylinder; and where the force and reſiſtance of the thin plate is ſtronger, the chord being then in the ſharpned or leſſer part of the top or cone, eaſily ſuſtains that greater force by leſſer diſtances from the centre or axis, and by allaying it, tempers it.

You ſee then the whole perfection of Clocks, or Watches, which conſiſts in uniform motion, or equality, depends on the framing the foreſaid cone or top; which I deſire Artiſts diligently to obſerve, and to take great care in the making of it, that the moving force of the ſpiral thin plate be rendred

dred every where equally valid; neither is it ſufficient, as they are wont, to try it by hearkning to it whether the ſound be ſharper or graver in the ſwifteſt motion of the jagged little wheel G H, ſince 'tis not eaſy to diſtinguiſh the leaſt difference of ſound; wherefore 'tis rather to be done ſome other way, and Father *Schottus* propoſes two, the firſt is by weighing, *viz.* by a weight hung on a long arm leading the Cone about, for if which way ſoever the Cone be turn'd about, the ſame weight endeavours equally againſt the adduction or reduction of the Spire, the Cone or Top will be perfect.

Fig. 131. The ſecond way is meaſuring by time, for, ſays he, the little Wheels being ſet at liberty in a ſwift and free motion; take ſome very ſhort Pendulum, and by its vibrations examin the circumvolutions of the lower Wheels, for if the circumvolutions of each wheel be in equal ſpace of time, it argues that the cone or top is perfect: In the ſame manner, the circumvolutions or turnings round of the jagged little Wheel G H may be examined by a Pendulum, to wit, whether they are made in equal time, notwithſtanding if there be added weight to the foreſaid little wheel the motion is rendred more ſlow.

Problem. VI.

To mend the unequal motion of Clocks, or other Engins, by applying a Pendulum.

THe chief fault in Clocks, and all Engins that meaſure time, is the irregularity of motion, for no kind of Clocks to this very day is found, whoſe motion is ſo equal or uniform, that it errs not at leaſt a minute from the true meaſure of time, in one day or 24 hours, although it hath been the ſtudy and endeavour of many ingenious men; in the firſt place, we are indebted to *Mathew Campane* to this end, that by the accurate meaſure of time Geographers may obtain the knowledge of Longitude, and what proficiency they have made in it, you will underſtand by what follows.

Truly 'tis doubted whether any man can by application of a Pendulum, compleatly perfect the little jagged Wheels of Clocks, and take away their inequality; therefore the Author of that famous Invention, deſerves to be followed and praiſed of

of all Men; and since there are divers ways of application in this kind, some whereof we have described just before, it remains that we reckon up some others in this place, either more ingenious, or also more useful.

Fig. 132. Let there be a Pendulum I L, with a wire fixt to the Axis C D, which rests on the two poles C and D, and in the middle part of its Axis, fasten here and there two little wings, or thin plates of mettal, extended according to the length of the Axis, or in an Horizontal site, above this Axis let the upper wheel of the Clock A B be turn'd, being made by a peculiar art; to wit, let it be made in form of a Zone, with a double row of Teeth disposed to the end of the Zone in such a double order, that when the Teeth, or little Keys that stand out, being considerably distant from one another, each tooth of one row, answer to the middle space of teeth of the other row; for so by turns they will hit against the aforesaid two wings, to wit, one tooth or little key of the row towards the right hand, on the righ wing, and the other row on the left hand, on the left wing; again, the other on the right, on the right wing, from whence are made the Altern Vibrations of the Pendulum. If then each of the two rows consists of ten teeth, in all they will make twenty; and the Pendulum must be of such length, that each composed Vibration answers one second of time, there may be fitted on the same Axis of the wheel the Tympane F with six teeth, which will be moved by the wheel G H of 36 teeth, for this will absolve one circuit in the space of a Minute; so that an Index fastned to its Axis, may note every second in a circle divided into 60 equal parts; and beneath the Wheel G H, another may be fitted, which may be turn'd about in the space of an hour, and its Index may shew the minutes, moreover another which may shew the Hours, *&c.*

But something offers it self worth our noting in the application of Pendulums to Clocks; in the first place, if a weight doubley or tripley greater be hanged to a Clock, it is not the reason of moving it notably swifter, or the cause of making the hours visibly shorter, because in this case the Pendulum is forced more vehemently, and therefore makes greater arches in its Vibrations; it seems that it ought to move more slowly, and to make the hours longer, if it be true that is said in the Book of Pendulums, that the Vibrations which are made in a greater

greater arch from the same Pendulum are longest; but experience tells us, that the Hours are somewhat shorter if weights are hung much greater, and the reason is, because the wheel which is called Serpentine, or the wheel meeting with the beam of the Ballance by way doth not permit each Vibration to run through the whole Arch which they would run through, and therefore cuts them off a little shorter.

Secondly, For this reason Pendulums ought to be a small matter longer than if they were altogether at liberty, least each of their vibrations be made in a shorter time than is meet.

Thirdly, You ought not to use a string or little chain, because they will bend, but a wire, or in greater Pendulums, a rod of Iron, or other Mettal.

Fourthly, Since in these kind of Clocks the augmenting or decreasing of weights signifies little to the swiftness or slowness of motion, but the swiftness or lowness depends almost wholly on the length or shortness of the Pendulum; therefore that Clock may be reduced to the just measures of Hours, the Globe, or Ball, ought to be fixed to the lower end of the Rod, in such manner, that it may be raised or depressed, and that may be done if there be a screw made on the end of the Rod, which is engrafted to the Globe more or less, and binds it very well that it slide not down, which inconveniency may be prevented by another concave Screw P, which keeps the Globe aways in the same place.

Fifthly, 'Tis better to hang a heavier weight to a Clock, or make use of a stronger Spring, and to apply a Pendulum a little the longer.

Sixthly, The Vibrations ought not to be too great, but the Pendulum ought to swing backward and forward to the height of 30 or 40 degrees in its arch.

Seventhly, Clocks made with Pendulums, require much greater weight or stronger Springs than others, which are regulated by the ordinary simple poisers, so that sometimes a triple weight is required to it, than is required to a Clock without a Pendulum; nevertheless for divers reasons, according to the manner or fashion, a Pendulum may be fitted, it may require more or less weight in the precedent artifice, unless the little wings of the Axis C D be made long, it will require a great weight; as appears from the principles of Mechanicks.

Eighthly,

Eighthly, Greater Clocks which are furnisht with greater Pendulums, in like manner require weights in the ſame proportion, or alſo in a greater than the times of the Vibrations have, or which is the ſame, in ſubduplicate proportion of the lengths of the Pendulums; for Example, let a Clock have a pendulum of 36 inches, or 3 feet, which makes each Vibration in one ſecond, and another with a pendulum of 9 inches, which abſolves the vibrations in half a ſecond, ſo that in one hour that makes 3600 vibrations, and this makes 7200; ſince the pendulum of the firſt Clock is quadruple of the other, to agitate it, is required a quadruple force or weight; becauſe it ought to move but doubly ſlower, alſo the Serpentine wheel, or that which incites the pendulum, muſt be moved doubly ſlower, and therefore the weight hung to the lower wheel will have a double weight, therefore a double weight ſuffices to move a pendulum of quadruple length through like Arches; for a double weight, if it have over and above a double poiſe of another weight, is equivalent to a quadruple weight.

Fig. 133. Notwithſtanding 'tis to be Noted, if the longer pendulum be inforced in a point proportionally diſtant from the centre of the pendulum, a weight as little again will ſuffice to move the long pendulum, as if the pendulum A C, receive an impulſe from the upper wheel in the point B, and another longer pendulum D F, receive an impulſe in the point E, and let the proportion be the ſame of A C to D B as of D F to D E, a weight doubly leſſer is required to move the longer pendulum than to move the ſhorter pendulum; for if the diſpoſition of the wheels be the ſame, or the velocity the ſame as the upper wheel, an equal weight is required as appears, but in a longer pendulum the upper wheel is moved doubly ſlower, and ſo the weight hung to the Clock hath a double poiſe, therefore a weight doubly leſs ſuffices. But if the pendulum D F be impelled in G, ſo that D G be a mean proportional between A B and D E, than an equal weight in each Clock is required, and only double the weight is required in the Clock of the pendulum D F, when the pendulum is incited in the point H, ſo that D H be equal to A B, and the Globes C and F are ſuppoſed of equal weight, but if the weights are unequal, then their proportion ought to be had, which may vary diverſly.

Problem

Problem. VII.

Another way of fitting a Pendulum to a Clock.

Fig. 134. HEre we will deſcribe the way moſt in uſe of fitting Pendulums to Clocks, the ſerpentine or encountring wheel, muſt be placed in an Horizontal ſite, and the beam of the Ballance alſo ſtretcht out Horizontally on the ſame; the wheel furniſht with jagged teeth, muſt have its number unequal to this, that two little flaps, or wings, of the Beam of the Ballance, may lay hold on the teeth by turns, according to the uſual manner, which little wings ought therefore ſo to be joined to the beam of the Ballance, that their planes make a right angle, and the Axis of the beam ought to be extended preciſely through the centre of the Wheel; but becauſe if the Pendulum be immediately join'd to the beam of the ballance, its weight will burden it too much,therefore a handle is added to the beam, boared through in the extream point, to which hole is fixt a rod hanging at liberty that it may eaſily agitate.

But you muſt take care that the lower little arm poſſeſs a middle ſite between each little wing of the beam of the Ballance, leſt one vibration of the pendulum be greater than another, and make the motion very incongruous and lame; in the reſt obſerve the precepts already delivered; ſome fix a Globe unmoveable on the end without any Screw, moving the centre of the Spear or Wire, they raiſe it or depreſs it to reduce the vibrations to the exact meaſure of time, for when the centre is raiſed, the pendulum runs through a leſſer arch, and ſooner diſpatches each vibration, ſpecially becauſe 'tis reſiſted by a leſſer impulſe, and it makes the vibration ſlower, if it be depreſt for the contrary reaſons; yet you muſt take care that the centre be not beneath the axis, nor that it be elevated much above it; laſtly, the length of the little arms are determined by practice, and by the wheels.

Problem. VIII.

To amend the Irregularity of all Clocks and Engins, measuring time otherwise than by the manner of Pendulums.

I Know ſome have not been wanting, who are willing to adopt Pendulums to watches, or portables Clocks, nevertheleſs they laboured in vain; for the ſmallneſs of the Watches, and the diverſity of their Scituations, with the continual agitation of the pendulums, while they are carried about, cannot eaſily admit them to vibrate uniformly; and although the pendulum may be ſo fitted, that being librated between many circles or rings, after the manner of a Sea Needle, it may always obtain a perpendicular ſite; however the agitation of the whole watch will make the vibrations of the pendulum to run ſometimes in this, ſometimes in the other part, hindering their equality altogether, beſides that, the ſpace which the beam requires, is much greater than the magnitude of Watches will conveniently admit; wherefore perchance more patly, the whole watch with its pendulum appled to it after one of the foreſaid preſcriptions, may be hung within 3 or 4 little circles, which may eaſily be included in a Sphærical caſe of the Watch.

Since therefore the application of Pendulums to theſe kind of Watches, or other portable Engins, are either uſeleſs or altogether difficult, the illuſtrious *Hugenius* (for his new Invention, now known to all the World) hath found out another way, which I could not paſs by in this place, it being very profitable and ingenious, therefore accept it as taken from Letters of the ſame Author.

The Miſtery of the Invention conſiſts in a thin plate of metal or ſpiral creſt, having faſtned to it at the lower end a Catsgut String, or an Inſtrument of an equal weight, but greater and more ponderous than is wont, and movable of its own accord to and fro upon its points; and the other end is faſtned to a little part or covert ſticking up above the upper part of the Clock, which being once vibrated to the tongue of the Ballance of the Clock, compreſſes and releaſes its ſpires one after another, and drawing to it ſelf a little help coming from the wheels of the clock, maintains the motion of the Inſtrument or Ballance ſo truly, that although it makes greater or

leſſer

lesser digressions, its reciprocations nevertheless throughout are equal in time one to another.

Fig. 134. In the figure of the former Clock the plane is A B, the circle of the Ballance, or compass about the tongue of the ballance C D, its axis or lance E F; the wing or spring turn'd into a spire G H M is fastned to the spear of the ballance in M, and to the thin plate of mettal on the upper plane of the Clock in G, so truly, that all the spires of the spring cleave to these two props hanged up in the air, touching nothing beneath: N O P Q is a certain covering, or propping, in which the other point of the ballance is turned: R S is one of the toothed Wheels of the Clock, having a certain motion of the poiser imprest on it from meeting with the next wheel, and this wheel R S is folded into the Tympane T, made fast to the axis or spear of the poiser, whose motion is by this means as much maintain'd as there is occasion.

This Invention of *Hugenius* may be used not only in Watches, and portable Clocks, but also in others which are put into motion by hung weights; and to which he adds, That a clock made by the foresaid Artifice may be serviceable in finding the Longitude at Land and Sea, which I am not easily induced to believe, for neither is the inequallity of motion of Clocks more corrected by this Invention than by Pendulums, as you may easily understand by what is said, nevertheless 'tis very useful, because it may be fitted to portable Clocks, or Watches, which cannot suffer a Pendulum.

Fig. 135. I observe that the spear of the ballance E F may agitate, and unless I am mistaken, more beneficially by a Zone or double wheel with smooth teeth, or little keys after that manner, whereby a pendulum agitates in the fifth problem, to wit, if the little keys C, D, G, H, *&c.* by turns, or one after another, hit against the two little wings A and B, here and there fixt to the same spear or lance; for since this spear ought to be much thicker and stronger than commonly they are wont in common Clocks, and more resists the impulses of the wheel S R, by reason of the spire G H endeavouring against it, the poising wheel commonly call'd Serpentine is not so useful, which is wont to agitate the common spear of the Ballance.

Problem. IX.

A Clock that makes no Noise, and yet hath a Pendulum.

Fig. 136. IT will not be unpleasant in this place to describe a kind of a Clock which we found in Father *Miliet's* third Book of Statics, or art of ballancing, *Prop.* 59. where he hath these things.

This kind of Clock, or Watch, is most usefull, because no sound of the Poiser is heard; and therefore may be used in a Bed-room without fear of disturbing ones rest.

The Lord *Setale* hath had many of this kind made, and the Artifice was thus: The Clock consists of 4 wheels, and one axis furnisht with little wings or Pinions.

The first wheel was furnisht with 96 Teeth, and dispatcht half a circulation in an hour.

The second had in the axis 12 little Teeth, and in the circumference of the wheel, it had 72 little Teeth, and it accomplisht 4 circulations in one hour.

The third had 6 little teeth in the axis, and in the circumference 60 little teeth, and finisht 48 circulations in an hour.

The fourth had 8 little Teeth in the axis, and in the circumference 80, and finisht 360 circulations in an hour.

The axis furnisht with wings which is described in the Figure *e e*, had 8 little teeth, and finisht 3600 circulations in an hour, and since every circulation made one compounded vibration, there was 3600 compounded vibrations, and 7200 simple ones; one compounded vibration is equal to a second Minute, and a simple one to half a second minute, the length of the pendulum was 9 inches.

The whole Artifice consists in the axis B C, and in the handle of the pendulum H I K, which may be turned about the point G, as about an axis, and the point K was ingrafted in the point 6 of the axis, furnisht with rings, which axis while it turns, inforces the arm K I, and draws it in by turns; which you may easily conceive, if the arm K I be at right angles with the axis B C, and be ingrafted in the point 6; the rest may better be conceived if the thing be put into Execution, than can be exprest in words.

Problem. X.

To determine the number of Teeth and Wheels in Clocks which have Pendulums.

THis practice ought not wholly to be neglected, which is most useful in directing Artificers, especially since it also contains a method of beginning, and reckoning the number of vibrations and circulations of wheels, which is very necessary in the construction of all other Engins.

The foresaid Author began these reckonings, together with the foresaid method in divers forms of Clocks, beginning from a Clock which consisted of two wheels only; for although it is difficult to fit that pendulum, nevertheless if it be accomplisht it will be very exact, since the meeting of many wheels induce always a greater inequality in motion.

Fig. 137. In the first place therefore (saith he) let there be two wheels, the first or lower of 120 teeth, which is supposed to finish two circulations in hour, wherefore it will be equivalent to a wheel of 240 teeth: The second wheel hath a little wheel of 5 teeth, wherefore while they pass through 5, of the teeth of the greater wheel, the second finishes one circulation, therefore you must know how many times 5 is found in 240, which you will know by Division, and the quotient will be 48, wherefore the second wheel makes 48 circumvolutions in one hour: And it appears, that the second wheel of 35 teeth, each of which effects two single vibrations, since it touches the poiser twice; wherefore each circulation makes 70 vibrations, multiply 70 by 48 and you will find 3360 single vibrations in an hour, the Pendulum will be Feet $3\frac{1}{2}$, and somewhat more.

Fig. 138. I will propose another not unlike the precedent: Let the same wheel have 120 teeth which will make two circulations in an hour, and therefore will be equivalent to a wheel of 240 teeth: The second little wheel shall have 6 teeth, divide 240 by 6 and the quotient will be 40, the second wheel then will be turn'd round 40 times in an hour, and shall have 45 teeth; and because, as I said but now, each tooth touches the poiser twice in each circulation, this number will be doub-

led

led and will make 90, which number multiply by 40, and you will have 3600 single vibrations in an hour, that is, each single vibration will be equal to a second minute; the length of the Pendulum must be 3 feet 3 inches and $\frac{2}{10}$ of our English feet.

Or if instead of the 6 teeth of the little wheel you put the teeth of the little wheel 5, for then the second wheel compleats 48 circulations in an hour, and there will be 4320 vibrations in an hour, the length of the Pendulm will be about two feet.

In the like manner, if there be given the first wheel making two circulations in an hour, and of 150 teeth; the second wheel, or that which encounters with it, shall have a little wheel of 5 teeth: Wherefore the division being made of 300 teeth (which are in two circulations) by 5, it will make 60 circulations: Suppose 60 teeth in the second wheel, that is, 120 vibrations in each circulation, it will make the number 7200, and the Pendulum about 9 inches, that is, each single vibration will be equivalent to half a second minute.

Fig. 139.

The same things being observed, except that the first wheel compleats only one circulation in an hour, you will have the number of vibrations 3600, and the Pendulum will be 3 feet, that is, each vibration will be equal to one second minute.

Which Examples I have put only, because you may learn the method of finding out other numbers, which shall seem more fit.

A Clock with three Wheels.

You can scarcely make Clocks with Pendulums which shall have only two wheels, unless you make the Wheels very great, and abundance of teeth: Wherefore the greater are commonly made of three Wheels, and the lesser of four: I shall exhibit in this place some numbers: A Clock hath 3 wheels, the first of which hath 112 teeth, and the second little wheel 7, the second wheel hath 60, the little wheel, or axis of the third wheel hath 8 teeth, the meeting wheel 15, you will have the number of Vibrations thus, Divide 112, the number of teeth of the first (which in each hour is once turn'd about) by 7, to wit, the axis of the second, and you will find the second to be turn'd about 16 times; and the second hath 60 teeth, wherefore multiply 16 by

Fig. 140.

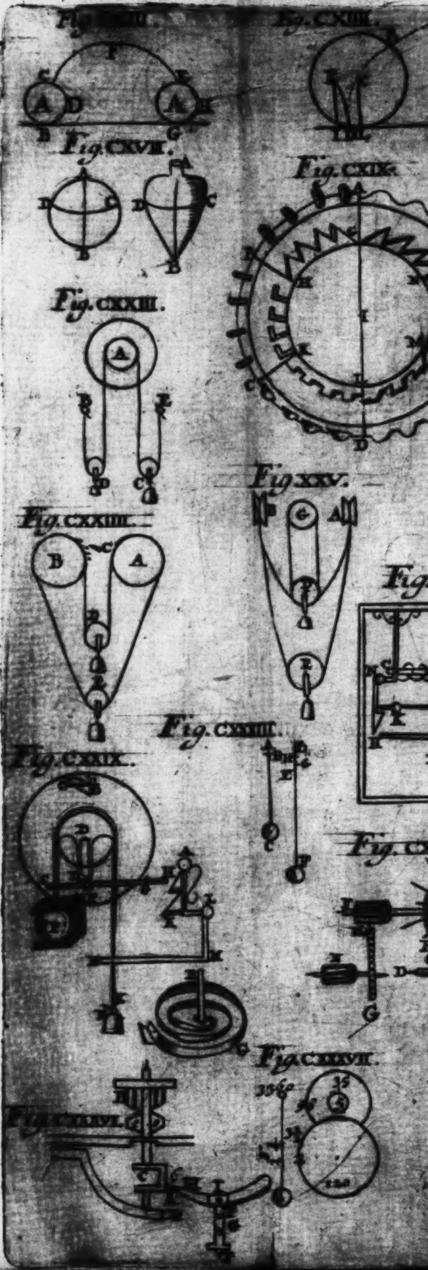


Fig. CXVII.
Fig. CXIX.
Fig. CXXII.
Fig. CXXIIII.
Fig. XXV.
Fig. CXXIX.
Fig. CXXXVII.

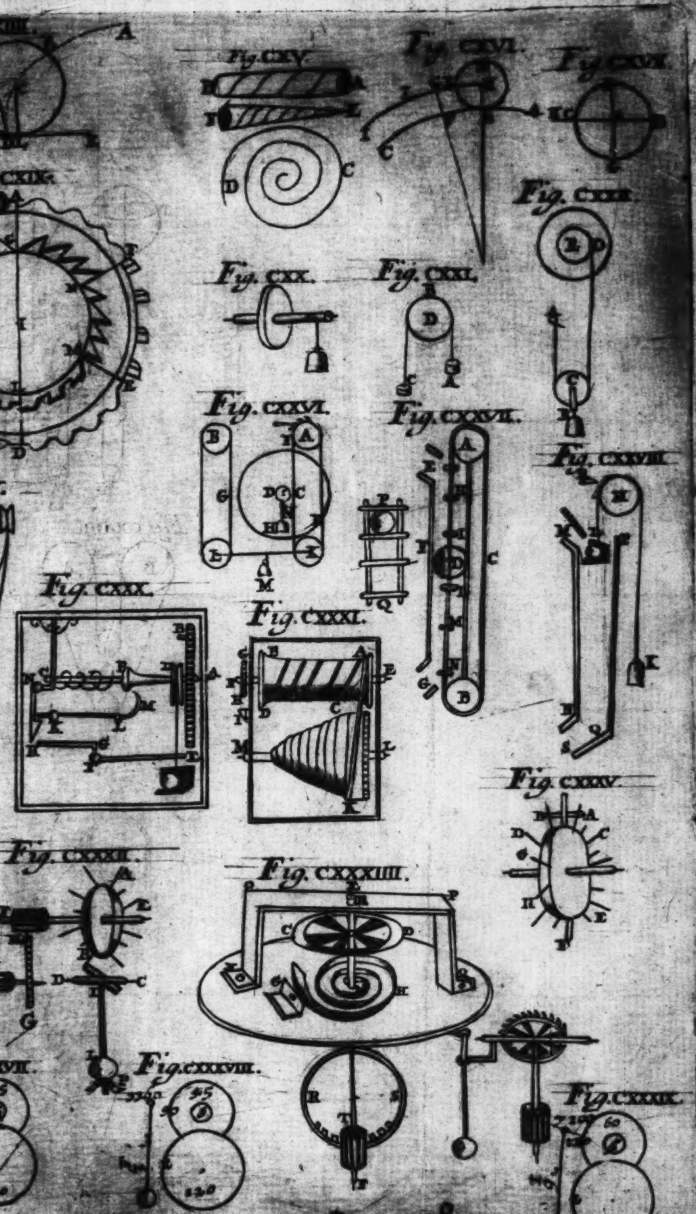


Fig. CXV.
Fig. CXVI.
Fig. CXVII.
CXIX.
Fig. CXXII.
Fig. CXX.
Fig. CXXI.
Fig. CXXVI.
Fig. CXXVII.
Fig. CXXVIII.
Fig. CXXX.
Fig. CXXXI.
Fig. CXXXV.
Fig. CXXXII.
Fig. CXXXIII.
Fig. CXXXVIII.
Fig. CXXXIX.

by 60 and you will find 960, therefore it passes over 960 teeth of the second in an hour, which number you must divide by 8, the axis of the third, and you will find the third to make 120 circumvolutions, and it hath 15 teeth which make 30 single vibrations, multiply 30 by 120 you will have 3600 single vibrations, and each equivalent to a second minute, the length of the Pendulum must be about three feet.

The same is better done by other numbers: Let the first have 96 teeth, the axis of the second 6, the second 45, the axis of the third 6, the third 15, and this length of 3 feet is best for great Clocks.

The 3 following numbers give the number 7200 vibrations in an hour, that is, 2 vibrations in one second minute, to wit, the going and returning, and the length of the Pendulum 9 inches.

	Vibrations 7200.				Vibrations 7200.	
order of wheels.	Circumvolutions.	Teeth of wheels.	Circumvolutions	Teeth of wheels.	Circumvolutions	Teeth of wheels.
3	144	25 5	144	25 5	144	25 5
2	15	48 5	12	60 6	$14\frac{2}{5}$	50 5
1	1	75	1	72	1	72
Length of Pendulum 9 inches.			Pend. 9 inches.		Pend. 9 inches.	

In the succeeding Table the numbers described give the Vibrations 7600 and 10000, with the Length of the Pendulum 8 inches and 4 inches and $\frac{2}{3}$.

	Vibrations 7600.				Vibrations 10000.			
order of wheels.	Circumvolutions.	Teeth	Circumvolutions	Teeth	Circumvolutions	Teeth	Cir.	Tee.
3	200	19 6	200	19 5	200	25 5	200	25 5
2	20	60 6	20	50 6	20	50 5	20	50 5
1	$1\frac{1}{2}$	80	2	60	$1\frac{1}{3}$	75	$1\frac{1}{4}$	80
Length of Pendulum 8 inches.			Pend. 8 inches.		Pend. 4 inches $\frac{2}{3}$		$4\frac{2}{3}$	

The

The following Numbers are for a Clock, which makes 10800 Vibrations in an hour, or 3 in one ſecond minute, the length of the Pendulum 4 inches and $\frac{1}{4}$, and others alſo, as may be ſeen in the following Table.

10800		10800		14400		11400		11400		10944		9600	
216	25 5	216	25 5	288	25	300	19	300	19 5	288	19 5	320	15 5
$22\frac{1}{2}$	28 5	18	60 6	$28\frac{4}{5}$	50 5	30	50 5	25	60 6	24	60 6	$26\frac{1}{3}$	60 6
$1\frac{1}{2}$	75	$1\frac{1}{2}$	72	2	72	2	75	2	75	2	72	2	80

The following Numbers are for a Clock with 4 Wheels, the number of Vibrations in an hour are 10800, to wit, 3 Vibrations anſwer one ſecond minute, the length of the Pendulum is about 4 inches $\frac{2}{3}$.

10800		10800		10800		10800	
360	15 6	360	15 5	360	15 6	360	15 6
60	36 6	60	30 6	60	36 6	60	36 6
$7\frac{1}{2}$	48 8	9	40 6	8	45 8	8	45 7
1	60	1	54	1	64	1	56

Theſe Tables were made by the foreſaid Author, wherein the Printer had committed ſome Errors which we have amended, that they may be uſeful to Artificers.

If in the laſt Table you take the numbers propoſed, changing only the number 15 of teeth of the upper wheel, and in its place uſing a wheel of 20 teeth, you will have a Clock which

which will compleat 14400 Vibrations in an hour, to wit, 4 in one second minute, and the length of the pendulum will be Inches $2\frac{1}{4}$; nevertheless because many Artificers will have the meeting wheel to have an odd number of teeth, they observe the precedent numbers, to wit, so that only the last wheel but one which finishes 60 circulations in an hour hath 48 teeth instead of 36 teeth, and makes the same number of Vibrations 14400.

Wheels are divided many other ways, and the Clocks are commonly furnisht with Pendulums; some are so disposed, that the serpentine, or encountring Wheel, is turn'd round 60 times in an hour, and is furnisht with 60 teeth, and finishes two vibrations in one second minute; or hath 30 teeth, and finishes one vibration in a minute, then the number of the teeth themselves inscribe the minutes which appear conspicuous through a round hole, or through a little opening made in the front of the Clock.

Problem. XI.

To correct perfectly the inequality of motion of Clocks, or other Engins that measure time, having Pendulums, by applying a double Pendulum, and by Cycloides.

ALthough a Pendulum applied to a Clock (as we have said) effects this, that if the impulsive cause of motion of the wheels be too swift, or too slow, its vibrations tempers it, each of which when they measure a determinate time, either they agree to the too much celerity of the wheels, or they stir up and excite their heaviness and dulness, whence for the most part the irregularity is taken away; notwithstanding because while the Pendulum resists the unequal impulses of the wheels, their vibrations must needs contract some irregularity to themselves, so that some make their excursions thro' greater and others thro' lesser arches; and it appears by what has been said, that those Pendulums finish their arches in shorter time which make the least arches, and those in longer which make greater or larger arches: Hence 'tis, that by application of a Pendulum all the Irregularity is not wholly corrected, unless the Clock be so fitted that the vibrations be truly regular and uniform.

And this irregularity of Vibrations may proceed from a threefold head; the first is, the various temper of the air thro' which the globe passes, for if it be thick it resists more, if heavier, the motion is not only consequently hindred by the greater density, but also the weight of the globe is rendred less ponderous, that therefore they have less strength to cut the air, and it renders the motion of the wheels and the *Impetus* more faint and weak. The second is, the impulsive force of the wheels, or other power, continuing the vibrations, which if it be irregular, induces in like manner at least some, if not all, the Irregularity in the vibrations, and these two heads may be referred to outward causes. The third is from within, or from the nature of the vibrations themselves, which are, as we have said, that if a globe fall by its own weight, in swinging it will make many vibrations, yet they will not all be of a like continuance.

The irregularity of Vibrations which proceed from the first head may wholly be taken away, if the Clock with the Pendulum be included in a case of glass, or such like receptacle, wholly unpassable to the air (which how to perform we shall shew hereafter) wherefore it remains that we speak to the two other.

To the Irregularity of the third head, which is as it were inbred in the simple vibrations themselves, a remedy seems to be found by the industrious *Hugenius* by the following ingenious practice, the whole Art consists in a double arch of the figure of a Cycloid, within which the Pendulum agitates.

Fig. 141. Let the Pendulum be A B, which is agitated to and fro by indifferent arches B C, B D of 20 degrees, and let this Pendulum hang by a thred or small cord A E of one inch more or less, according to the length of the Pendulum, whose remaining part E B must be stiff; dispose here and there near the centre A two bowed thin plates of mettal A G H and A F I, so that they touch the lines A D, A C, in the points F and G, and the curvity ought to have the figure of a Cycloid; so it will come to pass that if the Pendulum make greater vibrations, and runs out beyound the lines A C, A D, it will touch the Cycloid in the points F and G, and its length will not any longer be A D but F D, and so when the Pendulum is made shorter, its vibration continues less time: But why the Author chose rather the figure of a Cycloid than another Curve doth not sufficient-

ly

ly appear, nor doth his Demonſtration ſeem to be lawful, whereby he pretends to ſhew by this Cycloid that the length of the Pendulum is made leſſer and leſſer ſucceſſively, while it hits againſt the thred A E, and that that leſſer length preciſely compenſates the greater length of time of the vibrations which are made by the greater arches.

The manner of deſcribing the Cycloid,according to the Author, is two fold: Firſt, deſcribe a Circle whoſe diameter A B is equal to half the length of the given Pendulum; take in the circumference any number of equal parts both ways from the diameter as A C, C D, D E, E F, and A G, G H, H I, I K, and join the parallel lines C G, D H, E I, F K, then make the right line L M equal to the Curve or arch A D F, and divide it into as many equal parts as there are in the arch, to wit, into 4 parts, one of theſe parts of the line L M transfer from C to N, and the ſame transfer from G to O; moreover two of theſe parts L M transfer from D in P, and from H in Q; likewiſe three of them from E in R, and from I in S: Laſtly, all four from F in T, and from K in V, and by the points A, O, Q, S, V draw a line, and alſo by the points A, N, P, R, T, and they will be portions of a Cycloid, between which the Pendulum muſt be hung from the Centre A; the right line L M which is to be equal to the arch A D F, he teaches to find in this manner: Make X Z equal to two chords, ſubtending the arches A D, D F, then take X Y equal to the Chord A F, of the whole arch A D F, take the third part of the difference Y Z, that is Z A, and add it to X Z, and X A will be a right line equal to the arch.

The ſecond way is Mechanically; on a plain Table, place a Ruler A B half an inch in thickneſs, make alſo a little wheel or cylinder of the ſame thinkneſs C D E H, whoſe Diameter make equal to half the length of the pendulum; then a thred or ſtring F C H E being faſtned in the point F of the rule, and in ſome point E of the Cylinder, ſo that part of it be wound about the Cylinder, and the other part extended on the ſide of the rule F C; in the ſame Cylinder fix an iron ſtile D I, which ſhall deſcend a little below the lower baſe, and exactly correſpond to the circumference of the Cylinder; theſe things thus diſpoſed, if the Cylinder turn about on the ſide B A, towards A, ſo that the ſtring be always wholly ſtrecht, the ſtile with its point I, will deſcribe the cycloid line I K, and in the ſame

manner, you may deſcribe another like and oppoſit unto it, and you will have the figure M K I, which repreſents the ſpace between the two crooked pieces of thin mettal, between which the pendulum ought to agitate, ſo as to make all its vibrations in equal times.

Another late invention of *Mathew Campanes* conſiſts altogether like to a double Pendulum, which is ſo fitted to the Clock, that one of them moves and makes a certain number of vibrations, the other reſting, and by turns while the firſt reſteth the other finiſhes the ſame number of vibrations; and in this manner, 'tis agitated by one after tother, that as ſoon as one reſteth, the other begins to move; for if a pendulum of its own accord and proper weight falling from ſome certain height of its arch, make 100 vibrations in the ſpace of one minute of an hour; 'tis certain that another exactly like the former will efect the ſame number of vibrations in the ſame ſpace of time, provided it fall of it ſelf from the ſame height; to wit, the impediment being removed in the ſame manner which detain'd the pendulum from falling from that Altitude; wherefore if two pendulums are ſo fitted in a Clock, that they are both every where alike, and falling from an equal height finiſh 100 vibrations in one minute, they will move one after another, nor will one begin to move until the other has finiſht 100 vibrations, and no irregularity can intervene in the meaſure of motion, ſince each compleats 100 vibrations in one minute preciſely.

And the Clock may be ſo diſpoſed, that while one pendulum makes its vibrations, the other pendulum not only reſts, but neither any of its wheels of the Clock are moved, beſides ſome one deſigned for the purpoſe, that as ſoon as the other hath made 100 or 60 vibrations, it removes the impediment which detain'd both the pendulum and the Clock, and detains the pendulum firſt in agitation to reſt at the ſame inſtant that the other together with the Clock begins to move; then again, the Clock with the pendulum reſteth the impediment being removed from the motion of the other pendulum.

This may be done many ways, as any one inſtructed and exerciſed in Mechanicks may eaſily underſtand; the Author ſhews one way, which becauſe he hath not ſufficiently explained it, 'tis in vain to deſcribe it here.

And although I think this kind of Clock furniſht with a double

double pendulum to be most exact, and scarcely to err one minute in an whole day, that is, in 24 hours, if it be well kept in some Chamber, and be placed in an unmoveable site; yet if you make use of it in Navigation to find the Geographical Longitude, I cannot esteem it wholly to satisfie what is desired, for two Reasons; first, because it can scarce be in the agitation of a great ship, but the whole Clock must conceive some motion, or at least a light shaking or trembling in it self, although it be artificially fixt on movable poles, or hangs on movable circles; from which trembling or shaking, the vibrations of the pendulums must needs suffer some irregularity.

The second reason common to all kind of pendulums is, because while the pendulum is moved together with the ship, it makes not a circular motion, but another motion mixt of a circular and a right; yea, if the ship besides an Horizontal motion be agitated by other motions, chiefly upwards and downwards, as happens many times in an unquiet Sea, the motion of the Pendulum will be mixt of a Circuler, Horizontal, and of other motions both right and crooked, nor at any time uniform, from whence it comes to pass, that while the centre of the pendulum is irregularly moved, its vibrations will be irregular, and it will run through some times greater and some times lesser arches, or rather crooked lines, and altogether unlike between themselves, as we have shewn before.

Problem. XII.

To reduce the continual moving, and irregular Powers of Clocks and Engins, to a regular and uniform motion.

Since in the preceeding Problem we have taught ways and means whereby the finite and irregular motions of Powers may practically be reduced to equality of motion, nothing seems now to be wanting, unless 'tis to shew how to obtain a motion equal and uniform in powers infinite or continul, which otherwise of their own nature are irregular; which, if it be done, we shall attain to a motion continual, and altogether equal; nevertheless I do not mean that continual motion which is altogether mechanical, or purely artificial (of which in its place) but the other which is called *Physico-Mechanic*, because that it partly consists of Art, and partly of Nature; for since no moving

power seems to be continual or perpetual, unless it be natural, or depends immediately on a natural cause, as we shall manifest hereafter, and these kind of natural powers or virtues in nature keep not always an equal order; it is requisite to find out an art whereby we may effect that their force, although unequal, may neverthelesss be serviceable to the perpetuating of a motion equal, and altogether uniform.

Therefore I call all those perpetual moving powers, or natural and irregular, to which we are apt either immediately or mediately to apply new weights, or regular powers, within some finite and determinate time successively, and always to the Engin being once made.

And all the industry and art which is to used in this matter, may easily be gathered from what we have said in Problem the 5th, for if we suppose a Clock to be made, whose motion according to the rules prescribed just before is absolutely uniform, and it should go so for eight days by some weight hanged to the lower wheel, that in that space of time, it shall want no help, if then within that same time of 8 days an infinite power, or a perpetual natural one be artifically applied, that shall be fit to raise another weight equal to the former, and to deposit it in the place of the former, so that forthwith the weight of the Clock likewise shall descend to the bottom, and be placed in the subjected channel, the Clock will be moved again by that new advanced weight, according to the artifice in Problem the 5th. aforesaid, and that will also keep it going 8 days, it is plain that the motion of the Clock will be equal and perpetual.

But Note, that you must use two weights at least, one whereof must be hung to the Clock, while its regular motion moves forward, the other by an irregular power (suppose Wind, Rain, Heat, Drought, *&c.*) is substituted in its place, before that hath discharged its office.

Moreover these two weights ought to be Sphærical, that one may easily succeed the other, the devolution being made by a channel, or plane, somewhat declining, as in the same 5th problem is shewn.

Lastly, 'tis convenient that the motion of the Clock be long enough, and lasting, before the weight descend to the lowest place, for this reason, that the natural powers may serve turn a sufficient time in the interim, that the other weight that comes

in

in place of the former be drawn up; for although the foresaid power be perpetual, yet it acts not always, or at least so little sometimes, that although at some times it be more strong, oft-times neverthelesſs a time may be expected for some hours, or also days, wherein force convenient may be attained by the successive and irregular series of natural causes; that you may more clearly understand what is meant when we speak of perpetual motion, for then we describe various perpetual motions *Physico-Mechanic*, from whence it appears of what use natural powers are, and by what art they are applied, that their force although irregular may notwithstanding perpetuate a regular motion to any Engin; I will offer only one Example in this place, by which you may easily judge of the rest. 'Tis already known to Artificers, that by small Breaths, or from the smoak of a Kitchin Fire, spits are wont to be turn'd, that is to say, dispose in the centre of the Chimny (which if it be Cylindrical it will be the better) a cross, or some wheel, furnisht with wings made of Tin, in the same or like form as is before described, for so while those wings hit obliquely against the Smoak, they carry the wheel about, and if there be in the axis a toothed Tympane, it conveys that together with it self, by which means it moves other wheels annext to it; a weight somewhat Sphærical put into a little Basket, may be raised to a certain height, and there put down according as we have said at *Problem* 5th. And to raise this weight which is fit to animate the Clock in motion 24 hours, it will not be needful that wood be always put on the fire, but a fire a few hours will be sufficient each day, if the Clock which is to animate by the weight raised by the Smoak, be proportioned to that weight. Wherefore in this, and any other like artifice, first you must examine how much weight may conveniently be raised by a natural power in a limitted time to a perfixt height, and then make the Clock or Engin proportioned to such weight.

What we have said concerning Smoak, may take place in Wind blowing, and Wings impelling, which will raise weight by annexing wheels, also if any one in a City, or the Gate of an House, dispose a threshold, or little Bridge, with an occult leaver, or a spring of thin mettal plate a little elevated, so that by the entring or going forth of Men, of Horses, and of Chariots, a weight may be depressed oft-times in a day, from each force a weight of some bigness may be raised a little, and so

by

by repeated motions may be drawn to a designed height for the perpetual animating of any Engin.

Problem. XIII.

A Clock animated, or going by Sand, persevering in motion many days, and shewing the Hours, and also Striking.

AFter the application of weights, or moving powers, we come to those Engins, or measurers of time, in which the circular motion is most apparent, and since there are many Hour-glasses that belong to perpendicular motion, or to an inclined plane, it remains for the perfecting of them, that we shew how (approaching to circular motion) it may be effected that they may turn themselves by motion of their own accord after the flowing or running of the Sand, and that not once, but many times one after another, that therefore we may not only be freed from the inconveniency of attending the last flux of the Sand, while we are conversant in any other business, but also that it may not want any help of the hands for several days, and each turning about may successively shew the Hours, or likewise Strike: Mark what follows.

Fig. 143. Suppose A B an Hour-glass with Sand, such as is commonly used, in the middle whereof fix a transverse axis G H, and in an Horizontal site, and to the same axis let there be firmly fitted two Pullies, or rather Cylinders here and there, movable with the axis by means of weights Q and R hanging from them; above the Hour-glass make another Horizontal axis I K, movable about the poles I K, to whose side annex an immovable arm L M, with a weight M affixt to its end; and in the middle in like manner, let another little arm N O parallell to the former descend, which may be detain'd in its extream part O, or rather elevated together with the weight M, by a little wing standing out from the upper base of the Sand, so that being hindred by the weight M, the Sand cannot be wholly turned by the weights Q and R, notwithstanding it will remain in a site not altogether perpendicular, but somewhat inclined; and the weight M must be so proportioned to the weight of the Clock, and also to the weights Q and R, that it may be detain'd in the said inclined site, untill all the sand be descended from the upper glass A into the lower one B, and when all the Sand is run into the lower glass B, it will obtain greater

greater weight, that therefore while the Sand endeavours to be placed in a perpendicular site, or in the line of direction, the weight M will rise higher, and at once will free the little wing O from the little arm N O, from whence follows the turning of the Hour-glass by means of the weights Q R, and the lower part B will be placed in the upper part, and will be detained by the little arm N O, by means of the little flap or wing P, untill the Sand is again run out; for then it will again be turned as before, and so successively until the weights Q and R are quite descended; but because the little Cylinders C E, on which the ropes sustaining, the weights Q R are turn'd about, may be of a small bigness, and because after every hour they make but half a revolution, it appears that the motion of the Clock and the turnings may be extended to many hours.

But if you would fit an index to shew the hours, that you may easily obtain by means of two little teeth, fixt on the end G of the axis G H and opposite to each other, which successively and by turns one after another, every turning of the Hour-glass will move forward the wheel G T, furnisht with so many teeth as there are hours described in the circle, which may be noted by a standing index fixt in the centre of the same wheel; but if in like manner you affix an hour wheel in a convenient place to the same Engin, which may be moved forward by means of some toothed Tympane, or wheel, by the same axis, you may cause the number of hours to be heard by striking on a Bell.

Many other ways the index may be fitted to the same Engin, and the striking of the hours may be made, as will appear by what we shall shew hereafter, when we shall treat of the indexes of Clocks, and their striking.

Problem. XIV.

A Clock moving by the Consumption of Oyl in a Lamp.

Fig. 144. MAke a Lamp whose part A B entertaining the Oyl, is like a Column or Cylindrical, shut close every where, except in its lowest part C, where the Oyl enters slowly through a little opening into a vessel annext C L, while the other Oyl is consumed by the flame L; in the foremost part

I N make a certain channel, and ſolder or glue it to the foreſaid Cylinder, within which on the upper part make a ſecret or hidden pulley I, with an axis E F, preſenting or conveying on the outward viſible face the index of the hours deſcribed in the circle G H.

Theſe things being done, put Oyl into the Lamp, or Cylinder A B, upon which let a cube D of light matter (as Cork, or Wood) ſwim, and to this you muſt faſten a thred, or cat-gut D C G I M, *viz.* that it may deſcend from the upper ſuperficies of the Oyl to C, and being put about the little pullies C C, it may aſcend to I, and be folded about that pulley; and laſtly, let the other end M ſuſtain a weight, yet of leſs gravity than to draw downwards the cube D, which muſt always Swim upon the Oyl, and while the Oyl conſumes, it deſcends with the Oyl, and draws the thred, or Cat-gut, with the weight M, and turns the pulley I, together with the hour Index.

Note, That the magnitude of the little pulley I, muſt be proportionate with the deſcent of the Oyl, and of the cube D; wherefore we muſt obſerve how much the cube deſcends in one hour, to the end that the little pulley moving, the index I may be moved orderly.

Moreover the receiver muſt be uniform, and of one thickneſs, and muſt make uſe of the ſame number of threds that the Oyl may be conſumed uniformly, and the Lamp may be fill'd with Oyl, either by a little door, or wicket, beneath C, or by ſome hole in the upper baſe of the Cylinder A, which afterwards muſt be diligently fenced from the Air entring in with a Screw.

If the axis of the little pulley I be ſo fitted within the Cylinder A B, that its end F ſtick out on the out-ſide by a hole made in the ſame Cylinder,and turn about the Index, you will obtain the ſame effect without the channel on the exterior part I N, which is made to cauſe the artifice to ſeem occult and miſterious; but that hole muſt be ſo fitted to the movable axis within it E F, that there appear no admittance for air into the Cylinder A B, for if there be, the Oyl will wholly deſcend, and be poured out without the veſſel C L.

Alſo the index of the hours may be made in the upper baſe A, of the Cylinder to fit, ſo that the baſe it ſelf be for the hour circle, which may eaſily be obtained many ways, as will appear to any induſtrious Artificer.

Laſtly,

Lastly, Besides the circle and the hour index, there may be applied a toothed wheel, by whose means the hours may strike; and if to make it more ingeniously, you would place a little Bell within the Lamp to give notice of the hours, you must solder or glue an open tube spirally to both ends of the inward superficies of a concave Cylinder, descending about the Cylinder; and through this tube, or channel, descends the Oyl while it wasts by degrees, and a globe of light matter swimming on the Oyl within the tube; then all things being so fitted, that in each hour the motion of the Globe in descending, finishes one whole spire, and then it hits against a pestle, or some flap, or wing, which looses the movable wheel from the weight, as is wont to be done in common Clocks with wheels, so after the finishing of each space of the spires, the Globe unloosing the same wheel, causes new stroaks of the hours on the Bell.

Problem. XV.

To make a pulley Clock, or a Clock of meer pullies without any toothed wheels.

Fig. 145. THis artifice is proposed by Father *Schottus*, lib. 9. *Tecnic. Cap.* 10. *Prop.* 47. Let there be (says he) a little pulley A B about its axis, or also with a movable axis, to this join the perpendicular M N P, by the artifice in Problem the 3d, and that by means of a little rod M A; from the little pulley A B, suspend the pulley C D, by means of a perpetual knotty little chord, whether those knots be made of firm little balls disposed or fixt to the rope, or knots made by bending the chord it self, and cavities or hollowings of equal space from one another, to answer these knots in each pulley A B and C D; the pulley C D hath in its axis a little pulley E F made fast, from whence is suspended in the same plain manner the pulley G H; and so henceforward the pulleys may be continued as many as are needfull; from the lower pulley, *viz.* to the little pulley I K, of the pulley G H, hang the weight L, sufficient for the motion of the pullies, and of the perpendicular; all the axes of the hanging pullies must be moved not within a firm hole, but within a certain slit, or notch, cut from the top to the bottom, that while those perpetual chords and

the knots are contracted, or distended, the axes of the pullies may be raised, or depressed; the rest that belongs hereto, as the proportions of the pullies to each other, are easily understood from what is said before, all those pullies being agitated by the force of the weight L, will be moved circularly, and the perpendicular N P, freely moving in its centre or point of suspension, will be agitated by the little pulley A B, and the little rod A M: See the problem before cited, and the other ways of applying pendulums to Clocks before described.

According to the Author, the Pullies must be so disposed that their axes move within the slit, or notch, and that causes the Engin to work ill, for when the axes gravitate unequally from the other Pullies, or from the weight L hung to the Pullies, they are crooked or awry, and do not retain an horizontal site as they ought; wherefore the axes should rather be put into firm holes, and lest the chords be shrunk or stretched by wet, or drought, they may be wove of metallic threds, or wyres; but if you use common chords the axes must be put into slits, and not into holes, but the pulley ropes ought to be doubled, and the weight hung to the lower little pulley, to wit, to the axis of the pulley C D, another little pulley equal to E F must be fixt, and you must answer the same in the opposite face of the pulley; which little pulley in like manner with another perpetual chord must sustain the same pulley G H, or rather another altogether like it, and annext to it: Lastly, another small pulley like to I K must answer on the opposite face; then the weight L will be parted in the middle, and will be sustain'd partly by the little pulley I K, and partly by the other opposite.

Problem. XVI.

To render the motion of a Pendulum continual for many hours, or also whole days.

MAny Artifices have been invented in the last years of this Age, and various ways thought on of rendring or effecting the motion of Pendulums continual, that they may persevere for many hours or days with the same perpetual velocity; from whence also this advantage follows, that all the vibrations are made in equal times; some of these kinds of

Artifices I shall describe in this place, which seem to me most meet for the purpose, for any one of his own ingenuity may take occasion to think of others.

Fig. 146. First then, let the Pendulum be A B, to which at right Angles join the little arm A C, and let the upper wheel, or toothed Cylinder be D E, which being turn'd about draws with it another little arm D C, made fast in the base of its Cylinder near the circumference being round in the middle, and with a smooth pin, so that the little arm may be freely moved about this pin, and consequently while 'tis turn'd about the Cylinder, or wheel D, the little arm D C may be depress'd, or bore down, which conjoin in C with another little arm, and the angle C being inlarged will suddainly cause the lance of the Pendulum A B to be lifted up, which is join'd in A to the wood I L from whence being suspended 'tis detain'd, but nevertheless it freely turns about the smooth pin A fastned to the wood; then some sufficient weight being added to the lower wheel G, from this motion follows the motion of the wheel above it F, and this being in the middle (as it is wont to be in Clocks) turns about the uppermost wheel E D, which drawing with it the little arm of the pendulum, the same imprints a motion to the pendulum, as long as there is new rope which sustains the weight annext to the wheel beneath, or lowest wheel.

Note, instead of the Cylinder, or little wheel D E, you may fit a toothed Cylinder having a crooked handle, which will lay hold on, and turn about the little arm D C, such as is the Cylinder M.

Note also, by how much lesser the proportion of the diameter of the little wheel D shall be to the arm A C, so much lesser will the arches be that are described by the motion of the pendulum A B.

Fig. 147. In the second place let the pendulum A B be movably fixt in A, in its lance fasten the arm M G, which may easily run sometimes into this, sometimes into that part, and sustain it parallel to the horizon; from the middle part of the same arm M G stretch out wood or iron like a little fork, or two teeth, made hollow, sticking out as at L, which in its cavity or cleft admits the pulley E F, immovable and in an oblique site put into the axis C D; let this kind of axis be furnisht with a toothed Cylinder, which will be turn'd about by the

the wheel N, by means of the weight P being added to it, or by means of other wheels, as you pleaſe: The Engin being diſpoſed in this manner, while the axis I H is turn'd about of the lower wheel; in like manner the middle axis C D is turn'd about by the toothed Cylinder, and with it the little pulley E F, which ſince it obtains an oblique ſite, it cauſes the arm G M, into which it is put to run to and fro, and moves the pendulum A B.

Fig. 148. Thirdly, Suppoſe the pendulum D B, hanging from the arm A C, immovably fixt in C, and let the lance of the pendulum be ſtretcht out ſomewhat above the point A, from whence 'tis ſuſpended, to wit, in D; then fit the axis E F, ſuſtain'd in the middle by the arm F, to which join the toothed Cylinder L, and let this axis be ſtretched out through the hole of the arm F towards A. Laſtly, in the extream part of it near A, let it be furniſht with a concave Cylinder, and being cut oblique, ſo that the ſection G D make an Elliptic figure; the Point A from whence the lance of the pendulum is ſuſpended, muſt be in the ſame horizontal right line with the axis E F, and with the arm A C; moreover it ought to be preciſely in the centre of the ſame ſection G D, although becauſe of the cavity of the Cylinder the point of hanging remains free in the air.

Then while the toothed Cylinder L is turn'd round together with the axis E F, the Cylinder D G is turn'd all under one, whoſe extream or end being an oblique Section, hitting againſt the lance of the Pendulum it unites a motion like to the precedent.

Fig. 149. Fourthly, let the Pendulum be A B, whoſe axis A C carries with it two toothed Cylinders D and E, which in like manner here and there, lay hold on the toothed wheel D E, but with interrupted teeth, ſo that while one Cylinder lays hold on the wheel on one part, the other Cylinder lyes upon the oppoſite part of the wheel which wants teeth, and therefore the whole wheel ought to be divided into many rows of teeth in an odd number, and 'tis convenient to make each row of three teeth, and between one and the other row, a ſpace of teeth left vacant, as much as is occupied by three teeth; ſo as often as the weight ſhall be hung to the lower wheel H K, this being turn'd about, will move the toothed Cylinder F, which being in the middle, will move the foreſaid

ſaid toothed wheel, which biting the toothed Cylinders D, E, one after another, ſomtimes on one, ſomtimes on the other oppoſit part, will move in like manner the pendulum A B alternately.

And as in the foreſaid Engins, each vibration of the pendulum is made in a determined part of time; to wit, in one ſecond minute, or in 20 third minute, *&c.* the proportion of the wheels and of their teeth muſt be obſerved, as in this laſt Engin, if we would compoſe each vibration of the pendulum to anſwer one ſecond minute; in the wheel D E, diſpoſe 25 rows of teeth with as many vacant ſpaces between, the Cylinder F muſt be furniſht with 8 teeth, the wheel H K muſt have 96 teeth, the Cylinder G likewiſe conſiſts of 8 teeth, beneath which will be another wheel of 96 teeth, to which hang a weight; for in this manner 3600 compound vibrations will be made in each hour, each whereof will be equal to one ſecond minute; then make fit the weight hung to the lowermoſt wheel, with the length and weight of the pendulum A B, in ſuch manner, that the lower wheel be once turn'd about in an hour preciſely, for ſo it will come to paſs that the Cylinder G will be turned 12 turns, and the Cylinder F, together with the wheel D E 144 turns, and at laſt the pendulum will finiſh 3600 compound vibrations.

Inſtead of the wheel D E of diſcontinued teeth, you may uſe a toothed wheel common to Clocks, if inſtead of the Cylinder of teeth, laying hold on it, you uſe two little handles, which by turns ſhall urge and move forward thoſe teeth of the wheel, by laying hold of them.

Inventions of this kind are excellent, not only in being ſerviceable in continuing the motion of the pendulum, but alſo in making of Clocks moſt exact as is obvious to every conſiderate perſon; which Engins or Clocks have this utility and conveniency, that they ſcarce make any noiſe in their motion, ſince the pendulum is inſtead of a Ballance, which in common Clocks cannot agitate without noiſe.

Problem

Problem. XVII.

To make a Clock to shew the hours on both sides, after a new method, which by a weight hung to either of its sides prosecutes its course, and the index of the Clock proceeds forward in both motions consequently.

THe Author before cited teaches this Artifice: See the last Figure of the preceeding Problem, where we have taught the method of continuing the vibrations of a Pendulum; for if you rightly understand the construction of the Artifice of this Engin, 'tis manifest from thence, that if, while the perpendicular A B is agitated, the wheel K H suddenly changes its turning about to the opposite part, that is, it begins to move to the right hand, when before it moved to the left hand, the motion nevertheless of the perpendicular will in no wise be hindred; because that in whatsoever place of its arch, the perpendicular A B lays hold on unawares from its first acquired *impetus*, it will continue the same vibration; but for the following vibration, it will have the favoring impulse to it self, for as much as the parity of the rest is the motion instituted by the wheels in this, or that part.

The same may be obtained other ways, as is explained in the foregoing Problem, but chiefly by the *Figures* 146 and 148, but yet easier by application of a Pendulum, which we have taught at Problem 5; it only remains then that an index be applied so, that although the turning of the wheels be made on the opposit part, yet it always proceeds forward in the same part.

Fig. 150. Let the axis A B be continually movable together, with the toothed Tympane B, firmly adhearing to the axis, which forces the wheels of the Clock on both sides to this, or that part.

In the first place, fix on the same axis, two wheels with fingers, or claws, within which smooth holes being bored in the centre, and the axis being smooth will move freely; moreover put upon the axis two other Cylindrics G H, and I K, with saw-like teeth or jags, each whereof must be firmly put into the axis, and turnable together with it, the jags of these wheels bend to the opposit parts, and are stifned in the opposit parts by wedges, or little pestles C G, E I, each of which is furnisht with a little

a little pressing wing in pressing its power, that the pins bending forward to the Jags, admit the motion without much resistance, and these pins are conveyed by the finger'd wheels C D, and E F, to which are fixt smooth little pins holding them at liberty; lastly, to the two finger'd wheels, there must be added a third C E movable with the axis L M, and its fingers folding in both the fingers of the wheels C D and E F, it may be expedient that the wheel C E referrs to another site, to wit, vertical, (if necessity require it) the circle of the wheel being put in points designed.

Therefore the Tympane B with the axis and jag wheels G H, I K fixt in it, are turn'd in either part, for presently either of the jag wheels will be bound by its bar or pin, and render its finger as it were continual, which with the axis leads it with it self, and the wheel C E together; and because this infolds its fingers with the other wheels, it impells it but in the opposit part, in which its bar or pestle hinders not, in as much as the opposit jags, holding the former and admitting the motion on that part; now if the Tympane B change its turning to the opposit, then that which was first hindred by the pestle or bar will be loosed, but that which was loose lays hold on his jagged wheel, which then first begins to move in the same part, in which his finger'd wheel moved before, and since the finger'd motion is the same now as before, because continued in the same part, therefore the motion will be continued, and the half of the Fingers C E ; to which therefore an hour index being fitted, will always move forward into the same part whithersoever the Tympane B with the whole Dial is carried.

Note, First, That the wheel C E advancing always in this or that part, depends on the jaggs or saw-like teeth, reciprocally inclining, and turning towards this or that part, whence if the site of both of them be changed by inverting both the jag wheels, and the other face being applyed to its finger'd wheel (the pestles or bars of the Jags being also changed) the motion of the wheel C E will be likewise changed.

Secondly, if the wheel C E be led about by the hand in that part in which it was first impelled by the fingers C D, and E F, both those fingers will be moved, but the axis with the saw-like teeth wheel, resteth by force of this Construction if nothing else hinders, and may in the interim be turned in this or that part, while 'tis not moved sooner than the axis L M.

Thirdly, but if you will lead about the wheel C E by the hand in the opposite part, and not in it which it was decreed to move, no motion at all will follow, but the whole ſyſtem will be firm, and will ſtick, ſo that the reſiſtance of the hand detaining the wheel exceedeth, 'tis neceſſary to apply a proportionate power to the tympane B on each part of it, which is no leſs a Paradox than the former; this conſtruction extends it ſelf to many other Problems of motion, as the deducing the librating motion into Circular, to the recalling whatſoever irregular motion to a well order'd Circular, *&c.* as will appear in what follows.

Problem. XVIII.

The Hydraulic Clock of Father Bettinus.

THis kind of Clock is indeed very ingenious, and the invention of Father *Bettinus*, and afterwards increaſt and enlarged in many things by Father *Eſchinardus*, of whoſe work alſo I have often obſerved not without great pleaſure of mind, the like Engin made in the *Roman* College, which performed the effect beſt of any: Therefore leſt our work ſhould want ſomewhat of thoſe things which ſcent moſt of Ingenuity, we have tranſlated this from *Bettinus*.

The outward Artifice of the Hour Tympane.

Fig. 151. You ſee the expreſs form of the Tympane conveyed from the axis through the centre, whoſe apparent Pole is H, and the other pole not apparent, and of the chord I K L M N P, whoſe two ends are fixt in I, and the little pulley K (if you pleaſe of Braſs) with a ſmall weight ſtretching out the rope lightly, that beyond L it adheres about the occult pole: But the great weight under the pulley N while the rope endeavours to draw the chafed axis, and as it were toothed, afterwards moves the Tympane together with the Tympane and the number 4 aſcends, and after the Tympane movable pieces either of wood or iron toothed, whoſe form and art we will ſhew hereafter, and ſome ſuch you ſee Q, R, while they hit againſt the movable and changing plate of mettal S, it connects the handles T V X, being drawn together they raiſe the little hammer on the ſide of the little Bell Y to ſtrike the hours.

The

The art of changing the numbers in the hole, where 4, as it were, lies hid under the circular plane, as also the art of setting at liberty the teeth under the plane of the opposite Tympane, we will shew hereafter.

Sect. II.

The inward artifice of the Tympane.

Fig. 152. ONe of the circular planes being drawn aside the Tympane immediately shuts, and that on the other part opens, as you see in the figure annext; behold there appears to you the superficies of two concentric cylinders A B C, D E F within the Tympane, within the concave of the lesser the stays or props are G, H, in whose holes the axis of the Tympane is put, within the convex of the lesser, and the concave of the greater is the plane K, which is join'd to the cylindric superficies, and to the circular planes shutting the Tympane; through the little hole I of the small plane I K passes water to run, when the Engin is moved by force of the weight, and descending in C, the water is prest by the plane K I.

Therefore while the rope about the little toothed wheel, after H by the force of the weight weighing down to the parts beholding the left hand as F E, thrust through G, H turns the axis together with the Engin, and the plane K I descends and hits against the water, and presses it towards the parts beholding the right hand as M A; in the mean while the water trickles down through the hole, and by little and little the plane K I intercepts the middle between the water, until the water running between more and more through the hole I, and the plane K I ascending to the parts towards A D (or beholding the right hand) most part of the water which flows beneath the plane increases the force of the weight hanging about the axis H, and causeth the plane K I which now is idle in the parts A D with a little water (which it hath not as yet deeply flowing above it self) at length 'tis turn'd by A D with a swifter motion towards C (or to the parts beholding the left hand) and from thence it descends again and the water presseth, which again flows through the hole, &c. and so perpetually by turns the Engin is turned, the Orb compleating a rotation once in each hour.

 The

The art is, that the dropping of the water continue an whole hour, whiles that after a slow and insensible motion of the Engin for an hour, unexpectedly the Engin turns, in the beginning of the dropping; in which revolution the hour is struck on the back part of the Tympane, but in the forepart the note or figure shewing the hour on the dial plate is changed.

Sect. III.

An easy and most ingenious Art, whereby the number of hours are always changed, and also the hours are struck in the hour Tympane without the artifice of other vulgar movers.

Fig. 153. THE invention of which striking and changing you shall have here in a double figure: And first, that which belongs to the changing of the numbers shewing the hours; suppose on the fore part of the shut Tympane, the plane to be drawn aside with the inclosed little boards.

The circle A B C D exposes to the eye that plane on the fore part, to which is affixt in E and F the Hexagon plane, lessened in on side P Q a half part of one of the other sides; and that Exagon is the excentric to the circle A B C D, having a hole G common with the circle (which is the centre of the circle) in which the axis of the Tympane is conveyed through. The hole under A is that, under which the number of the hour Indexes appear on the other part in the little boards, which must be noted in the hinder part of the little boards, but in the figure for plainness they are noted in the face apparent to the eye; you see those little boards joined to little thin plates of mettal with corners, the ends whereof are movable about the fixt little pins within the little boards.

The outward form of the art you have in the seperate H, and at I and K; imagine then the little board H to be in his place between I K, and to stand upon the side P Q, which is only fit to receive one little board, the other sides being large enough for two, as you see in the Figure; then while H between I K shews the number (which you must conceive on the other part) of the first hour through the hole A, and the circle A B C D is turned with the Tympane slowly, suppose towards A, the little boards 7, 8 fit themselves to the side M L, and 6, 5, to the side L R, 4, 3, to the side R Q, and by reason of the obliquity,

ty, the little board H being removed from the side P Q, in its place succeeds 2, and shews it self under a form. Moreover H and 12 fit themselves to the side P N, 11 and 10, to the side M N; 9 and 8, hang down beneath L M, and 8 succeeds in the place of the middle 7 hanging down, *&c.* and three always hang down without, and beneath one side as you see 6, 7, 8, beneath M L; and by this ingenious, easy, simple, and wonderful art the little boards change by turns, and one after another they shew the hours, the number of hours being inscribed under an open bright hole.

Fig. 154. But that which belongs to the striking of the hours is thus; suppose on the back part of the shut Tympane, the plane being drawn aside with the inclosed toothed little boards, that plane on the inner part exposed to the eye is represented by the circle S T, to which is affixt in V X a pentagonal plane excentric in the circle S T, having a common square hole (which is the centre of the circle) in which the axis of the Tympane is put through; there are 6 little boards quadrangular with teeth (according to the number of hours to be struck) having bases somewhat less than the sides of the Pentagon, and they are made fast by the corners with thin plates of mettal movable about the ends as you see in the Figure, and as is done in the little boards of the hour indices in the antecedent circle.

That you may understand the form and art the better, you have set a part Z, suppose the thin plate (by whose impulse the little hammer is led to strike the hours) to be in *a*, and the circle in the Tympane to be turn'd from S towards *a* T, the little board B with 6 teeth or claws striking against in *a*, sounds six tinklings on the bell for the hours, and presently falls down beneath *a*; then B being oblique to the parts T, the little board *d* fits it self to the side *e*, and so of the rest in the Orb, as is said before of the little boards of the hour Indexes.

And it must be noted and effected, that the little boards with teeth of the circle S T, so agree with the little boards of the Circle B D of the antecedent figure, that they strike the hour, which is presently shown under the hole, the number of the little board in the circle B D being changed.

Also you must take care that the hour plate inscribed in the first Figure, *Section* the First, be diametrically opposit to the plane K I of the figure in *Section* the second, through the hole, of

of whose plane the water trickles down; and let the same hour plate be opposite to the little toothed board striking the hour (not shew'd in the plate) of the next following number, so that when the shining hour eye is below the Horizon of the hours Diametrically opposit to the little Bell, and in that eye they number of the hour is changed, in the same moment the toothed little board strikes the hour, which being changed the hour immediately appears above the Horizon.

About the hole I, in the plane K I, through which the water flows on both parts above and beneath the plane K I, in the back convex of the Engin are two broad holes, through which the water is poured into the Tympane, and when need requires is presently all taken out, and through the same holes appears the lesser hole I, in the plane K I, that it may be lookt after if any thing hinders the running of the water through that little hole, and those two greater holes on the back part of the Tympame, may easily be shut and open'd by two brass thin plates affixt with wax, or other fit glue.

And because in the beginning of the hours the Tympane is turned slower, afterwards always swifter, because of a lesser resistance of Water, therefore in one of the circular planes shutting the Tympane is put a thin plate of lead in manner of an hook, decreasing by little and little, *&c.*

Sect. IV.

Observations of Father Eschinard, *to be practised in making the foresaid Engin.*

THis Author learned in Experiments advises in the first place, that the Tympane be divided in four equal parts by Parallelograms of thin plates of mettal, one whereof ought to be boared through with a small hole, as is said, but each of the rest are to be boared with a double hole much greater, one near the fascia, the other near the inward axis of the Tympane; for hence it will come to pass, that after the water hath past through by the small hole in an hours time, then having obtain'd a freer passage, it permits the vessel to be turn'd about with a swifter motion, that in the interim the hour may be shown by a sign of the little Bell, or the next ellapst, or the next to come; for unless the other thin plates

are made with greater holes, the Tympane will rather return than run forward; wherefore likewise an instrument may be made divers ways for striking the bell, to wit, by making it so that those points take up somewhat in their swifter motion after the manner of a Leaver, as is wont to be done in large Clocks with wheels, one end of which Leaver while it falls down draws the thred to it self, and raises the hammer; also sharp points fixt to the tables may be so fastned to the hinder superficies of the tables, that they may directly behold the Tympane, as also the centre of the Pentagon may be otherwise taken, *&c.*

Secondly, The iron plates being washt over with tin, corrupt presently, unless it be fenced by some Sandarac, or varnish, fit for the business; Copper cover'd over with tin, or tin only of it self, so that it be very thin, is best of all.

Thirdly, Beware lest the place of the small hole be so, that after some time the magnitude of the hole be changed.

Fourthly, The Tympane must be $\frac{3}{4}$ of one Palm at least, both in length and breadth, for if it be less it will not succeed so well.

Fifthly, The most fit water he takes to be rain water distill'd, but if the vessel be made of glass, hot water will be better; and the quantity of water ought not to fill much less than half the Tympane, but especially it ought not to come to the inner axis, wherefore that axis will be the better, if it be made as small as possible; the other things to be compared with one another are, the littleness of the hole, the quantity of water, and the force of weight; but chiefly you ought to take care lest that hole be stopt, which ought to be at least as big as one arch.

Sixthly, He denies that the thing may be done with Quicksilver instead of water, both because it requires a greater hole to flow out at, and therefore also a greater Tympane, as also because it will pass out most heavily; lastly, because all mettal corrodes, and therefore the Tympane ought to be glass, which will be difficult to be made: Also he denies dust, or sand, to be fit for that service, since it ought to pass through a small hole by being comprest in the middle, which is done by those thin plates of mettal, which cannot be obtain'd by dust: He concludes, if any Liquor be found in which heat and cold doth not govern, that is most fit, so it doth not corrupt the matter of the Tympane.

Seven-

Seventhly, He asserts another such like Engin of his own composing, wherein he hath made a perfect Hexagon in the axis for the Pentagon, and about it seven Tables are gathered together in the same manner as above, every one of which bears before it one of the seven Planets described with its proper Character. Lastly, in the foremost face appears a circular thin plate of mettal, but that for one circular hole it hath six, each being described upon with some cœlestial Sign, beginning, *viz.* from *Aries*; then while the axis is turn'd about the Planets are moved to the West, but so, that in every circumvolution they go back to another Sign placed after it in due order.

Eighthly, He teaches in what manner one Tympane, so it be large, may suffice for striking the quarters of hours; says he, make a Vessel, which divide in 4 parts by 4 thin plates, and then divide it again, but in a contrary manner, that is, let it be cut by the plates in the Section which makes a circle, and take away, as it were, $\frac{1}{3}$ part of the vessel, whence there will be, as it were, two Vessels in the manner of one, then either of these will be divided in 4 parts; the plates which divide the lesser Vessel ought all to be double in a place, to wit, nigh the fascia, and nigh the axis, to be opened with large holes, and the plates of the greater vessel are boared double in a place, but with an unlike hole, to wit, one nigh the Fascia very small, and the other the axis much greater; for this is necessary to communicate the air to every part of the Vessel, otherwise the water will not pass freely through the small hole; lastly, put the water in so to the lesser vessel that it may almost touch the axis, but in the greater vessel as little as may; be for hence it comes to pass, that when all the water in the greater Vessel shall pass through the first small hole, before that (since 'tis but little) the impediment of the second thin plates hinders, in the mean while the Clock will be moved swifter, but because this way it rather returns than goes forward, therefore 'tis restrained by the water put in the lesser Vessel, which in the interim passes through the great hole; then while the Clock in this manner is moved, after every quarter of an hour it strikes on the little Bells the number of quarters elapst.

Note this one thing diligently, *viz.* lest that slow motion be too short, as not to suffice for the striking of the Bells as often

as

as is required; also note, that hence it necessarily happens, that the outer face of the Clock is a little changed; for otherwise it will follow, that in the middle of the second hour, the number of the hour appears not longer, which evil we may easily cure many ways.

Hence he concludes, that this second division of the Tympane may also distinguish the Tympane for so many hours, for hence, says he, proceeds great benefit, for you may as you please make the motion more or less slower for striking the bell, *viz.* if you put more or less water into the lesser vessel, although you leave the greater vessel untoucht; but in this case 'tis sufficient, if the greater vessel only be divided with so many thin plates; for the other plates are put only to restrain the too slow motion, as is said before.

Ninthly, Because those things which are said seem not fit to the striking of greater Bells, three vessels are to be made in this manner: Two of them must be divided into 4 parts in the main, as is said of the lesser vessel for the quarter hours, the third must be also divided into 4 parts, but the same altogether after the manner of the greater vessel for the quarters; the water in the first two vessels is put in as you please, but the same must be observed as in the lesser vessel for the Quarters; and in the third you must observe that which we have said of the greater vessel for the quarters: But now if to the end of every quarter the third vessel (as is usual in great clocks) lift up somewhat, so that it being raised a free course is permitted to the other vessels, to wit, to one of those in the end of the hour for striking the hours, and the other to every quarter for striking the quarters, the thing will be accomplisht.

Tenthly, The foresaid Clock hath this peculiar, that it makes no noise, nor the motion of the Ballance, nor the Wheels disturbs not nocturnal rest: Notwithstanding if you would make use of it to rouze you from sleep at an appointed time, you may easily do it, by taking all the teeth from the Tables, except one of them, which you must fix in such place and order, that after the prefixt number of hours it may strike on the bell, or make some other noise, as is wont in excited Clocks, of which we shall speak hereafter: There are also other ways more easier, as if you use to it the percussion of a weight, whereby one part of the equilibrated table depresses a

Cliggut, ſomething ſallying out into the room, and you may encreaſe or diminiſh the percuſſion of the weight, by making a greater or leſſer hole in the other three plates, which have large holes for the ſwifter motion, *&c.* But if you add one wheel, you will find ſeveral eaſy ways.

The Author concludes, that hence all thoſe Engins may be ſupplied by a ſhort Compendium, which are not wrought but by many Wheels, eſpecially in thoſe which want temperate motion.

Moreover he adds many other things to equip this Engin, and, *Firſt*, he ſays, the veſſel may be ſo accommodated in the outmoſt part, that at what time the Clock is moved ſwiftly, whether before or after the Strokes on the bell, little boards being placed, or ſuch like, as is wont in Hydraulic Organs, it will utter a conſort of muſick, either in ſome Cimbal, or on little Bells harmonically diſpoſed.

Secondly, If the Clock be hung after the uſual manner to a wall, and to its ſide, ſome plane table be made faſt to the wall through the length, that it be parallel to the horizon, upon that table may be placed the Sun in its courſe, a hidden ſtring being drawn which tends rightly to the Clock, which may be drawn by the veſſel in its circulation ; and on the wall you may diſpoſe in right order (in the way through which the Sun runs its courſe) the heavenly houſes, whence each hour, a little Image poetically adorn'd appears, which ſhews the hour on the right hand next elapſt of the Sun, and on the left hand it leads ſome of the heavenly Signs, or ſome ſign of the *Zodiack* addicted to that houſe, *&c.* thus thoſe little Images will appear every one to his time ; put croſs in the way by which the Sun paſſes, ſome little board, ſo that when the courſe of the Sun being moved by the ſwift motion of the Clock, being carried in its courſe, it hits againſt one end of the little board ; which if the little board be placed in manner of a leaver, it may ſo be accommodated that while one of its ends is drawn, by the ſervice of the other end with ſome ſtring added to it, the little image is brought forth to the Sun, and there left.

Thirdly, Beſides that heavenly motion, that number which ſhews the hour next elapſt may be ſo accommodated, that the ſame ſite and face may ſerve, as well in its Apogeon, as in its aſcent and deſcent, to wit, if there be put to the little plate

on one of its parts some tin, a little heavier, being so affixt to each table, that it may most easily be turned about its centre.

Fourthly, Almost in the same manner, in that circular superficies whose half part always appears divers small Images may be affixt, so that they always remain aright, by means of Tin, or some other heavy thing added to their feet, and in going forward they may shew the quarter hours, *&c.*

Hitherto we have added no Wheel, but if we add one or two, you will attain many fine effects. First, a toothed wheel may be so placed on the vessel, that its axis may fall right on it, and on the extream circumference of the vessel many iron stiles may be put, which while the vessel is turn'd about they move the overthwart wheel placed above, by hitting against its teeth, moreover you may constitute a Load-stone on part of the wheel placed above; now if you fasten an Image with a wyre, with an iron stile in it hands, according to the motion of the Load-stone, it will shew the hour, *&c.*

Problem. XIX.

To make the Indexes of Clocks, so that they shall describe not only Circular, but any other Figures by their motion.

IF any one would adorn the Index of a Clock with the Arms of some Prince, or City, to dispose it in the form of a shield, of a heart, of a cross, *&c.* so that the same being artificially made, or a small image, or any other sign performing the office of an Index, the numbers of the hours being inscribed on the parts of its figure, in whatsoever order they are disposed in, it will shew successively; or that an Eagle with its bill, or a Lion with its tongue, *&c.* There are divers Artificers in Father *Schottus Technica, Book 9. Chap.* 5. the most useful whereof we will here impart.

Fig. 155. To describe the most difficult figures of moving Indexes assume the artifice of a Parallelogram made in this manner: First, of solid matter, *viz.* of iron make four rules A H, A K, K L, H M, which in the points A, H, C, K, so join with curious small pins, that the square may freely be stretched wider, or contracted narrower; then to those portions or parts standing out on each side C L, C M, join by the same artifice

tifice as many more rules, but shorter, and if you will, decreasing in the same proportion, and in the connecting or joyning points, freely turning.

Secondly, On that face of the Index that lies hid towards the Clock, conceive a hidden toothed wheel CDEFGB, to wit, so as those Indexes that are wont commonly to turn once in 12 or 24 hours, in this being made hollow, or any other way fitted, understand a little Channel A C, so that within it a little nail, or pin C, may be put sticking out from the Parallelogram towards the Wheel, and may run to and again, this way and that way, without resistance.

Thirdly, Fix a small pin A in the Center of the toothed Wheel, and then between it and the other little pin C, which ought to run in the little channel or groove, a Spring, or some impulsing Spire, being put between by a Wyer of a competent thickness in the manner of a wreathed Cylinder screw, drawing aside as much as is requisit the little pin C, from the other fixt pin A; which Spire perhaps may more conveniently be made of a Serpentine plate drawn and bowed.

Fourthly, Propose now any figure which you would have the hour index describe with its point; suppose a Hexagon, or figure of six sides: Cut then in the plane of the Index a six sided hole CDEFGB, whose Center is A.

Fifthly, Upon the whole Parallelogram, and the hole that is cut, place some figure, as of an Eagle, or a Dragon, *&c.* so that its neck touch the texture of the Parallelogram and hide it, and the other part of the body be spread over to the hole that is cut; Moreover that Parallelogram being wove in the neck of the figure by more of the same Rules placed between, in the likeness of a net, and move artificially after the manner of feathers, or the Scales of a fish, *&c.*

The hour Wheel then intercepting the pin C in its groove, carries it a long with it; and this from the drawing pressing plate placed between A C, and the cut, Sexangular hole, or included between other limits, will cause the Eagle, having a crown, cross or star on its head, or a Dragon with his tongue or sting, to describe the same figure, and to shew the hours described in its limb.

In the describing of other figures, as of a heart, a rose, a shield, *&c.* the Industrious will find it easy; another motion may easily be given over and above, to a Lyon, an Eagle, or a Dragon,

Dragon, *&c.* that this ſpread his Tail, that toſs its Spires, the other open its wings, *&c.* and that either by the ſame artifice, or otherwiſe.

Problem. XX.

To perform the ſame more Compendiouſly.

ALthough the foreſaid Artifice is univerſal, and extends it ſelf to many figures, yet this preſent Propoſition may be reduced to practice, with leſs charge and trouble, eſpecially to the eaſier; as Ellipſes and Polygons, and moreover may be applied to other Paradoxical affections.

Fig. 156. Let A B C be a rod of mettal, having a round hole in A, but in C where it bends, it ends in a little ring, or other erect hole C E, through which paſſes another rod D E F, which bending in the like little ring F B, and in like manner made faſt to the former rod, and cloſe or touch each other ſo lightly, that they are carried on one within the other to and fro freely; in the end D is made an arrow, a little Star, or other ſuch like ſhewing Apex.

Secondly, Underſtand in that plane in which the number of hours are inſcribed ſome figure, *viz.* a Square to be deſcribed GHIK, and nigh to its deſignation cut a channel or groove of any depth, and its breadth, ſo that ſtanding out from the little ring it may receive the point B, that it may run freely in its Channel.

Being placed then, and fixt to the hole A in the Centre of the quadrate, and to the ſtyle B in the ſame cavity, if this whole joining together of the Index in the point A be turn'd about by the Axis of ſome Wheel, or led about circularly any other way, the end D muſt needs deſcribe a Square figure, or another after the ſame manner, as is the Channel in which the ſtyle B is led about.

Note, Firſt, the ſame Inſtrument may be more ingeniouſly made of two rules, in one of which a little channel is drawn out in length, and the curſor runs to and fro in the other by turns; but the Artifice may be ſo cover'd, that the contraction and diſtenſion of the rules cannot eaſily be noted, in producing the rule D E F beyond the centre A, *&c.* *Secondly*, If between the

the rings E and F you put a wire, or a divided plate of mettal, it will not be necessary to hollow it in the plane, but only cut it out from the thicker plane being laid upon the other, or by the rules that frame the Poligon.

If you affect Paradoxes, hence you may easily deduce, *First*, that by the continual drawing and revolution of one and the same common compass, you may describe a triangle quadrate, *&c.* for if one foot of the Compass be fixt in the hole A, and and the other firmly lay hold on the Style E sticking out, and being led about by the compass, the style will describe such another Figure D, and was the little hollowed Channel, or another supposed plane terminated by a certain figure.

Secondly, If you would describe a circle by the same opening of the compasses, and not from the Centre of the Circle, you may do it almost in the same manner, which doth not require that the point A with the foot of the Compass be in the middle of the figure, as is manifest.

Thirdly, you will increase the admiration, if you add the describing a Triangle, a Square, an Ellipses, *&c.* greater or lesser, with one opening of the Compasses, and you may effect it thus; Produce the length D E F towards A, and let the little ring or Cursor B F, have a screw, or turning joint in F, that the compasses remaining at the same distance, and only the relique D E F being drawn from, or intruded from all the rest, and the foresaid turning joint may be fastned in F: More may be added by the Ingenious.

Problem. XXI.

To make and incite a Chronometric Index to an Elliptic figure, by a certain and peculiar method.

ALthough both the foresaid Artifices serves to describe Ellipses, yet the Author adds another, taken from a peculiar Geometrical Instrument of *Guido-vbaldus*, or rather deduced from the same foundation.

Fig. 157. Three planes, or thin plates, are to be conceived, the first is of an indefinite figure, which is described by the Elliptic Index A B C D, this is boared through in the middle in the round hole H E F G, and moreover cut in with four slits at

at right angles which are I E, K F, L G, M H, and join'd together with a round hole, the length of the ſlits is as much as the Semidiameter of the hole.

The other Plate P L is circular, which hath on that part ſome Index which is laid open to the view of Spectators, being put upon the former ſlits, and therefore touches the foreſaid hole of the former plate.

The third plane of the orb is I K L M, touching the ſame hole on the other part of the middle, and of the ſlits of the plate, and this therefore lies hid all within; its Centre is the ſame with the Centre of the round hole, and it hath Glued or Soldred to it, two Segments above and below the Centre, being cut through by a circle on its Periphery, that perfectly fills the ſides of the hole, and razes while they turn within the hollow of it; the thickneſs of theſe Segments is the ſame as the ſlits of the plate, with which they are therefore equal and alike.

The conſpicuous Orb P L hath its Centre in that point, which is poſited in the Periphery of the Segment H E, Glued to the hidden orb M I K L; In this point a hole is made through each orb, to wit, the conſpicuous P L, and the occult M I K L, to which hole afterwards a ſmooth little pin is put, to join each orb freely.

In the conſpicuous orb P L on one face which beholds the middle, or ſlit plate, are fixt two little round nails I and N, of the ſame thickneſs as the breadth of the ſlits, within which they ought to run to and fro moſt freely; the length or height of the little nails or pins is the ſame as the thickneſs of the ſlits, and the plates, or ſomewhat leſſer, leſt thy touch the occult orb through thoſe ſlits, and raze it in the motion; they are diſtant from each other the interval I N, equal to the diameter of the hole.

In the inner and occult orb make the hole R ſomewhere, into which enter ſome little nail ſticking out for that end in the diurnal Wheel of the Clock, whether it be turn'd once in 12 or 24 hours, the Centre of which Wheel ought exactly to anſwer to the centre N of the hole H E F G, and alſo of the occult orb I K L M; the diſtance of the hole R, and of the little Nail anſwering it, will be the ſame *viz.* R N; it is the ſame, if in the diurnal Wheel of the Clock a hole be bored through, and in the point R of the orb a little pin anſwering it be fixt.

The foreſaid pin then being entred in the hole R, will cauſe the occult orb I K L M to move about, being laid hold on by

by the Wheel of the Clock, and will carry it forward from R towards M; and at the same time a hand being formed, a Lilly, the Sun, or such like, the Index P will proceed forward to the opposit part, and by its apex describe the Ellipsis A B C D, to which hours unequal spaces are described distinctly, which neverthelesss are finisht in equal time, to wit, hourly, by the Index.

Since the conspicuous orb P L, on this face, on which 'tis beheld, is altogether plane and whole, you may for ornament inscribe on it, either the Effigies of the 7 Planets, or the figures of the 12 Signs, which indeed have no other use, than that they are turned about wonderfully to and fro with the orb, that he that is ignorant of the structure, and its make, can hardly conceive it, because that the orb is moved with a double motion, one by which its Centre E is carried circularly about to the Periphery of the hole E F G H, and the other Elliptic, whereby the other parts of the orb are carried.

The Internal F H between the two Segments is therefore left, that the little nails I and N may pass in a right motion through it diametrically opposit without obstruction from one slit to the other. See Guidubaldus *in the Demonstration of the* Planisphere, *and* Bettinus *his Comments on the 28th. Proposition of the 6th. Element of* Euclid.

Problem. XXII.

Divers ways to make a right lined Index to shew the hours, or quarters of hours, by a right motion, aud then to return back again.

Fig. 158. Make a plane Wheel A B C D E F, whose middle part D E F A is furnisht with teeth, but none in the other parts, the axis A G H D lies directly over, or upon the Centre, or diameter of this Wheel, carrying two toothed Tympanes A and D, also two toothed Wheels G and H, which all firmly adhere to the axis A D: *Thirdly*, make the Oblong I K L M, three of its sides being of Solid mettal, and the fourth K M is closed by the figure of the Sun, or any other sign, moving forward by a right lined Index, which neverthelesss may be placed most conveniently in the middle of the oblong;

Fourthly,

Fourthly, to the two longer ſides I K and L M, make the teeth of the Wheels G and H to agree to the teeth of the other, *viz.* to the face of thoſe ſides which the Wheels G and H behold and touch, for that oblong is conceived to lie upon the Wheel G and H, and theſe to cover over the ſides I K and L M.

The half toothed Wheel moving then in the firſt place from A towards B, will move the Axis A D, with the Tympanes and Wheels in the ſecond motion, with which in like manner is carried on the oblong with the Sun K M from K towards B; and the length of the ſides I K, L M of teeth ought to be in the ſame ratio to the Wheels G and H, as the Semiperiphery D E F A to the Tympane A or D equal to it; Secondly, and becauſe the plain Wheel is furniſht with teeth only in the middle part, which begins to impel the Tympane A Firſt with its teeth, the Tympane D oppoſite to it is hindred by none, much leſs when the whole axis and Wheels are turned, and by an unanimous conſent both wheels G and H the ſides of the oblong, are ſo long forc'd forward by an uniform motion, as the channel'd Cylinder A is impelled; *Thirdly*, when firſt the toothed Semicircle approaches to the Tympane D, and begins to ſet its teeth in it, in the ſame moment the Tympane A is freed from the force of the teeth, and is turn'd to the oppoſite part, being led by the other; from whence alſo the oblong removes the track out of the way to the oppoſite part, as long as the toothed Semicircle forces, which it ought to perform 12 or 24 hours, or, if you pleaſe, but one hour: *Fourthly*, this whole artifice is hid beyond a certain table equal to the oblong of the Index, which therefore is divided into 12 equal parts, or hours, and the number of the hours are deſcribed in a double row, the uppermoſt of which from 1 to 12 ſhews the Aſtronomic hours from Midnight to Noon, and the lower from Noon to Midnight, or otherwiſe.

It may be done eaſier, for the weight in the ſpace of time in its deſcent of the whole height, either in a plane vertically erected in ſome place, the ſame horary intervals may be deſigned; and the ſame perpendicular motion of the weights may eaſily be tranſlated into an horizontal one, by a Pulley put between, on which put a ſmall chord, and bind it to the deſcending weight; or if you find that inconvenient, fit a Pulley, or Cylinder, in ſome Wheel of the Clock, meaſuring time by its motion, for a Chord being folded to the Cylinder ac-

cording to the various magnitude of the Pulley, or to the number of its revolutions made in an hour, will give divers horary ntervals in the plane designed on the Wall, or other plane of a competent length, in which, if you please, you may hide the Artifice, and within or behind the table of the right lined Index you may place a piece of load stone from the weight by the foresaid little chord to move forward slowly being loose, and without the table, in the sight of every one, may be moved by the hidden load-stone an Iron gilt with the Sun, or *Phaeton* driving a rosey Chariot, a Chamelion, or a kind of Sea fish, *&c.*

Problem XXIII.

To Effect the same another way more ingenious than the former.

Fig. 159. BEcause the foresaid Author appoints in the first practice, that the toothed oblong forcing the Index, and lying hid behind the table, while 'tis conveyed to and fro of its own accord, requires another space equal to the table to which it allows and extends it self: and in the latter way, whether he appoints it by finite or perpetual Chords, he doth it either by attraction of small Chords, or of the Index by a small chord, from whence 'tis moved forward, therefore I have thought on the following way whereby both those defects may be remedied.

Let therefore the whole length of the table of the right lined Index be A B, or C D; take a chord, or small rope, six times the length of A B, and join the ends to make it perpetual, as E A B F D C E; Put this about two Pullies, or Cylinders E and F, moving freely about their Centers, so that the small Chord pass occultly under the upper border, or limb of the table A B, and of the lower C D; Secondly, let there be also some Index as G, so fitted that it may move forward to and fro through the whole length of the table freely, which may be done thus; it may run to and fro within two little Channels, or grooves, cut in the upper and lower limb of the table, or by two other metallic Chords, or wyers, strongly extended and hung in the same limbs, and it strains them lightly with its

loose

looſe little holes, or rings, through which the chords are tranſmitted; then the Index G will be moved forward in theſe channels, or wyers, perpetually by the little rope to and fro in this manner: Becauſe the perpetual little chord is ſix times the length of A B, divide it into ſix parts, as A B, B F, F D, D C, C E, E A; moreover in the three points of diviſion A, F, C, omiting one interval, or ſpace, bind or faſten juſt ſo many inforcing flexible obſtacles with this condition, that paſſing by the perpetual ſmall chord through the two looſe rings of the Index G, *viz.* of the upper and lower, the obſtacle hitting againſt the ring of the Index moves forward the Index; and the Index arriving and conſiſting at the extream ſide A C or B D, the obſtacle being drawn by the perpetual chord, nevertheleſs going forward paſſes through the little ring of the Index overcoming that ſmall matter of reſiſtance. To this end you muſt take ſmall ſtalks cut off from the Quils of Birds, or Horſe, or Swine's hair, or the ſtrings of a wood-like White-thorn; then theſe three obſtacles being conveyed overthwart by the perpetual chord in the points A, F, C, and fixt; conceive now one of the pullies E or F to be annext with ſome wheel of the Clock, as with the diurnal when you would have the Index to be of 12 or 24 hours, or with the hourly, or quarterly, *&c.* if the Index ought to be hourly, or of quarters: Let it be hourly, and either of the pullies E or F to move regularly circular by the hour wheel of the Clock from whence it will be incited, or by another perpetual chord, or by a toothed Wheel, *&c.* And make the motion of the Pulley, and of the perpetual ſmall Chord, furniſht with the obſtacles, or ſmall ſtrings, or hairs, the upper from B to A, and the lower from C to D. Underſtand now the Index G, to be brought by the horſe hair, or other ſtring A, from B D to A C; Then becauſe the Index cannot paſs further, the horſe hair notwithſtanding being drawn by the perpetual chord, it will paſs through the ring of the Index, which it will lay hold on, and will paſs forwards towards E. At the ſame time the hair or ſtring C applies to the lower ring of the Index, and the Index being free from the former hair A, draws it back with it ſelf from C towards D, then the Index hitting againſt B D the Margent of the table, this lower hair will paſs through its ring, in the mean while the other hair F is now found above, which Index that it may remove it forces away, and this reciprocation

of the Index endures as long as the motion of the Clock, if you diligently obſerve what follows.

Firſt, Obſerve the Compendium in the beginning of this Problem; for whatſoever is without the table A B C D of the Index, you will contract to a leſs ſpace, if you wind about the Pullies E and F once or twice thoſe portions A E C, and B F D of the perpetual chord; for in this manner thoſe Cylinders, or Pullies, muſt needs be moved near to the table of the Index, and always to its top, as the Centers of the Pullies E and F anſwer to the extream limbs of the table A C and B D.

Secondly, to continue that reciprocation of the Index without any error, you muſt take great care that the precedent obſtacle, or hair, paſs through its firſt ring, and leave it before the ſucceeding one sieze his, which you may eaſily obtain if you do not permit the Index to come to the extream terms A C and B D, but a little before it touches them, 'tis forc'd to ſtand ſtill, and is freed from the former mover, that the other comming too, which was firſt diſpatcht by the former obſtacle, may find out the Index, which will be done in a ſhort time.

Thirdly, Becauſe at the firſt aſpect of this Index you cannot know whether it goes forward or backward, therefore the thing may be ſo ordered, that one Index in going may turn to the ſpectators a face of one colour, and the other in returning a colour contrary to the former. If yet the number of hours or quarters above, be gone forward from A to B, and the lower from B C, it will be known preſently at the firſt aſpect, whether the Index goes forward or backward.

Problem XXIV.

To make the ſame power which moves the hour Index to ſtrike the hours alſo.

FAther *Schottus* thinks it may be done by a ſpring, or ſteel ſpire; for ſince each ſpire after this manner hath two ends, central and circumferential, one of which being drawn, each returns to the oppoſit parts; ſays he, one end, *viz.* the Central, may force the Wheels of the Index, and the other the ſtriking Wheels, or the contrary; And he affirms that the irregular force

force and resistance of the spire may be made fit by the artifice delivered by us before, notwithstanding this must be diligently observed, that some certain time must be appointed by the Artificer, wherein the Clock is to be drawn up, and then according to the number of Pulses of each hour the other loose end will be made fit, the Cone of this other end forcing the chronometric Wheels; But in this practice some difficulties occur, wherefore I esteem the following practises of the same Author more apt.

Fig. 124. First, therefore conceive in the Figures of Probl. 2*d*, the two Pullies A and B, to be fitted to the two whirling sistems of the lower Wheels, that is, to their axes; one indeed to the Chronometric systems, or circumagent Index, and the other to the strokes designed; for 'tis manifest from the right understanding of hanging of weights, that one and the same weight D serves both for the carrying about the Index continually, and to the striking of the hour Wheels.

Note, First, the Pullies A and B in *Fig.* 124. must be understood to be so placed as you see them designed in *Fig.* 125. *Note*, Secondly, if you do not make use of a perpetual chord, but a finite, then you must conceive that Chord to be perpetuall dissected, and to each end a weight, or poyser, to be hung, to continue the Chord within the Pullies A and B. *Note*, Thirdly, both ways here requires this weight D to be as heavy again, as that which is sufficient to carry about the other Wheels all at once: If therefore to each single weight that motion should be effected, you may make use of this following (although more laborious) practice.

Fig. 160. *Secondly*, make the Axis A B strong, and like a tree, or Cylindric, and stablisht in the points A and B, put on to this two toothed Wheels C D and E F, each of which shall have in its Centre a Cylindric Tube A G and B H, join'd or fastned together moving freely about their Axis A B: And to the ends of these Tubes G and H, must be fastned a little orb, or Jagged Wheel G and H, having but few jags, or teeth, as 12 or 16, but very deep; *Thirdly*, to the same Axis A B between each Wheel in the middle place, put the Pulley K I made hollow for receiving the Rope, to which that one only weight must be bound, and this Pulley also must be movable about the unmoved

Axis

Axis A B; and in the Bases or Planes which behold each Wheel, must be Bolts or Bars, on both sides the same number, and made by the same Artifice on both sides; *Fourthly*, the Bar therefore M L, whereby the Pullies are joyn'd together, hath first of all a hole, through which and the ear or ring made fast in the Pulley, passes the little round Axis, moving freely in the joints forsaking that Bar: The same Rail or Bar towards the Axis of the Pulley, holds out a certain hook, or little arm, athwart, as in Leavers full of corners or nooks; and lastly, towards the other end L 'tis bent like a hook, or bill. *Fifthly*, the Rails or Bars being fitted in this manner in the ambit of the Pulley in any number, as 3 or 4, so that all together they answer the Jags of the Wheels G and H, understand between the Jagged little Wheel G, and the Pulley I K, some Lilly, or like flower to be put, cut out of a thin plate of mettal, whose little Leavers sticking out towards the Centre of the Pulley, press the points or little arms of the Bars or Rails, that in this manner the bars L M, strive or strain always against the cuts of the Jagged Wheel, and the same is done by the face of the other Pullies. *Sixthly*, to the Tubes, or hollowed Axes of the toothed Wheels, must be put some Cylindric Segments N and Q, upon the foresaid Axes or Tubes, movable freely to and fro; and join them to some firm Beam N O P Q, that according to the motion of one Cylindric Segment, the other may be moved with a reciprocal motion. *Seventhly*, make some ballance C K E, movable in the Centre K, about which the half toothed Wheel is conveyed with it, whose teeth answer to the slits or cuts of the Beam O P; A little arm is erected in the upper part of the same Ballance answering the little tongue, or cock, of common ballances, to this is affixt the Sphære R of a competent weight. *Eighthly*, to the Tube or hollowed Axis of the Wheel C D, is put the little orb A, or smooth Wheel, movable together with the former, nevertheless it hath in some certain place of its Periphery one triangular tooth erected of unequal sides, and of such form as you see in Wheels, with Jagged, or saw-like teeth, so that it's *Hypothenuse* rises up slenderly from the ambit, or Periphery, and at length is ended in the precipice of the *Cathetus*, this little tooth about the end of any hour, lifts up slowly the little arm C, then when the ballance C K E is inclined it pulls up the little orb A.

These

These things thus prepared, understand *First*, the Horometric System to be the superstructure of the toothed wheel C D, and the system serving to excite the strokes is of the other wheel E F; moreover from the pulley K I is hung some compentent weight by the Artifices proposed before in Problem the 2d.

Secondly, Understand the ballance C K E with the weight R to be inclined towards the chronometric Wheel C D, for so it will come to pass, that the Wheel half toothed K forces the Beam O P towards the same toothed Wheel C D, and together with the Beam, each Cylinder N and Q.

Thirdly, One of the hour Cylinders, *viz.* N, when in this manner it goes back from the jagged Wheel G, it thrusts down all those hooked rails or bars in its incissions; and by the contrary reason the Cylinder Q being moved to the jagged Wheel H, lifts up all the rails or bars on that part, so that the jags in the little Wheel H are in no wise laid hold on by them.

Fourthly, When in this manner the weight hung from the common pulley hath a connection with the Wheel C D, and none with the other Wheel E F, that Wheel only will incite, and not this, and that will be done in an hours space, until the tooth sticking out in the little orb A, begins to take up slowly the little arm C, and with it the whole ballance C E, and also the weight R.

Fifthly, The weight R being inclined beyond the line K R towards P, suddenly rushes to the opposite part with the cock of the Ballance, and together with the half toothed Wheel K, impels the Beam O P, and the Cylinders N and Q towards B; wherefore the Cylinder N lifts its hooked Bar, and the Cylinder Q lets it down, and this being received within the jags of the Wheel H, make firm the Pulley K I with the Wheel E F, and its Wheels pertaining to the striking, which unlocks the arm K E, by a certain Leaver which the Figure doth not express.

Sixthly, The hour being declared by striking, the ballance C E is again lifted up with the weight R, to the opposit part by inclining towards O, and that is done by the *Phonotactic* Wheels, especially by those which are thrust on immediately from the Wheel E F, and which for every blow or stroke is

wont

wont to go once round, and carries in it's Axis a certain heart, by help whereof through Leavers disposed to that purpose, it may be done very easily, the Impetus of the Wheels approaching from the collected motion.

Note, *First*, in stead of the Pulley K I, a toothed Tympane may be placed, which may be moved by another inferior Wheel, and it's weight, for the same effect will follow, by increasing the weight of the clock as much as the thing requires: Notwithstanding the forces of which may be hindred by a spring, or steel spire, but only in a fixt, or standing clock, for in a portable one the same foundation remaining of shutting by the bar LM, the other furniture of the Leavers will be otherwise disposed to work changes. *Secondly*, when the *Phonotactic* Wheels are incited by the weight, the motion of the Index ceases the same time, but after that manner that either 'tis of it self but little, or 'tis compensated from elsewhere; also it may be so made that between those strickings, the Index shall not move forward at all, but the more free description of the artifice, the brevity of time excludes. *Thirdly*, if the *Chronometric* Wheels are incited not by a ballance, but by a Pendulum, the Artifice may be effected easily, that that may be apprehended and included in the uttermost term of its arches, and then the weight being restored to its Wheels, 'tis unloosed into Vibrations, otherwise the motion of the Pendulum once ceasing, it cannot be stir'd up again by the weight only; the rest I leave to the Ingenious to consider. Thus he.

And truly this practice is very ingenious.

Problem.

Problem XXV.

To cause any strong blow or stroke usually struck on great Bells, by a Hammer, and by great Weights, to be effected by much lesser weight, and fewer toothed Wheels.

Fig. 161. LEt the Wheel ABCDEF be divided into 6, 8, or more parts, in the division of which points make so many joints for certain equal arms and equiponderant hammers, or Iron balls, or Globes, to be fixed, yet so, that the motion of any arm run not out beyond the quadrant of a circle, *viz.* DGH: To the Axis of this Wheel place a Pulley with a weight and one toothed wheel, which shall turn about a certain axis with a ballance, to retard the motion of the whole Engin, and also the impetus caused by this ballance, *&c.*

Rails or Bars then being advanced shutting up the motion of the Engin, after which some hammer, to wit, DG must be conveyed perpendicular to an Horizontal site, and a little beyond the hammer falls down with a force, and describes by its fall the arch GH, and on the brim of the objected Bell strikes a stroke, or blow, and because it touches only the extream of the Bell, 'tis presently withdrawn by the Engin from proceeding any further, otherwise if the hammer should rest a little while, it would hinder the sound of the Bell, some steel plate should be put between by the side, which should draw the Hammer immediately from the bell, and not hinder it from tending downwards: And in this manner, much lesser weight being disposed, forces the Hammer and makes the strokes more valid, because the Engin is as it were Æquilibrated: The same may be performed by Iron Spheres, or Globles, falling from on high on the bell, which Globe is again raised to the height by a screw with a small power. Or so many Globes may be placed in an upper place, as are required for all the striking of hours for the whole day, as also of each hour, *First*, one of them is freed from the obstacle that it may fall on the Bell, afterwards two, and after that three, *&c.* according as the number of hours require: The hours may be adorn'd divers other new ways to shew the distance of hours, for first,

if you would ſhew not only the hours, but alſo the quarters, you may do it by many ſmall bells, to wit, make uſe of five little bells, whoſe ſounds aſcends by degrees in a Muſical increaſe or proportion; and for the ſtroke of the firſt quarter, the meaneſt or loweſt little Bell will ſound Do, or, ut; for the ſecond quarter, Do, re; for the third Do, re, mi, then follows the ſtroke of the hour ſol, ſol, ſol, *&c.* ſo often as the preſent hour requires.

Secondly, the ſame may be effected by means of muſical Chords, to wit, if you extend them on a table made thin and hollow, either Parallel to each other, or as radius's meeting in one point; and they may be ſo fitted and tempered that two oppoſits give a Harmony, beginning from perfect and proceeding to imperfect, for theſe kinds of Harmony being incited, each hour by a diurnal Wheel with two chords, will ſignify the hour decreed in a bed chamber, which may be heard in a night without the trouble of noiſe; and the Impulſe of the chords may be repeated three or four times, leſt the hearing be deceived, if you have a muſical Inſtrument with keys, you may uſe a Phonotactic Cylinder direct to the Clock, with a weight hung to it, by which it will be turn'd about.

Thirdly, the thing may be effected likewiſe by the Pipes of Organs, for if the Phonotactic Cylinder be made and applied to the keys of the Organ, and the Bellows being drawn either artificially by ſome eaſy Engin, or being once drawn perſiſts ſo, and they muſt deſcend by little and little each hour while the ſound of hours is required to be made.

Fourthly, the Strokes of the hours may be made by a military Tympane, or drum, and that moſt eaſily, as to any Induſtrious perſon will appear; yea, we affirm it is not difficult by Engins to exhibit to the ears, any ſtrokes or blows wont to be declared by Tympanes, with as much dexterity, as it can be done by the moſt skilful Muſick Maſter, both as to the Celerity of the blows and the difference of inequality of Percuſſion, and alſo as to Harmony or the ſounds of Tympanes in Muſical conſort. *Laſtly*, there is no Muſical Inſtrument, the Tube or Trumpet perhaps excepted, but it may be ſo fitted to a clock, as to make divers Harmonical ſounds each hour.

Problem.

XLI.

Fig. CXLII.

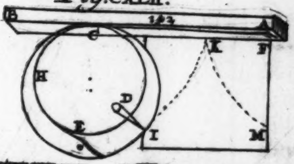
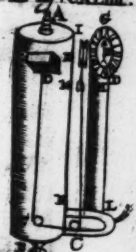


Fig. CXLIII.



g. CXLV.

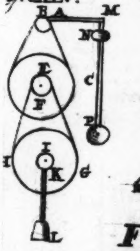


Fig. CXLVI.

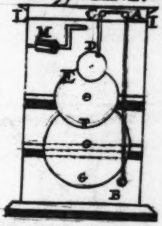


Fig. CXLVII.

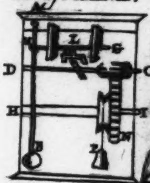


Fig. CLII.

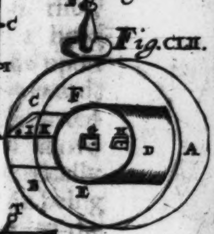


Fig. CL.

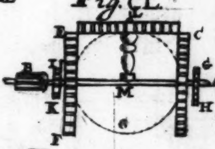


Fig. CLI.

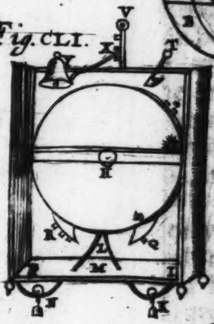


Fig. CLIII.

LV.

Fig. CLVIII.

Fig. CLVII.

Fig. CLIX.

Fig. CLX.

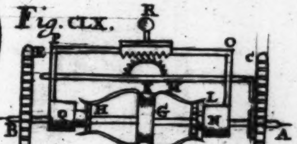


Fig. CLXI.

Fig. CXL.

Fig. CXLI.

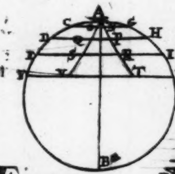


Fig. CXLV.

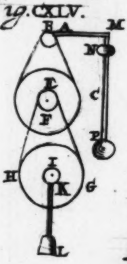


Fig. CXLIII.

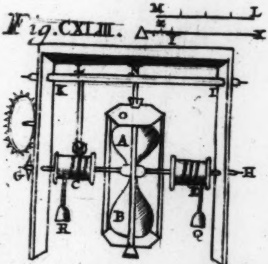


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Fig. CXLVIII.

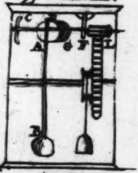

Fig. CXLIX.

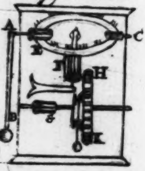

Fig. CL

Fig. CLIII.

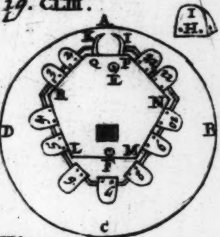

Fig. CLV.

Fig. CLVII.

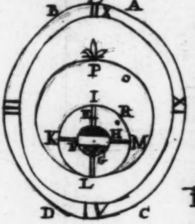

Fig. CLVI.

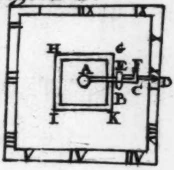

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Fig. CXLII.

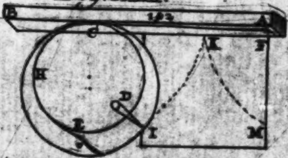


Fig. CXLIII.

V.

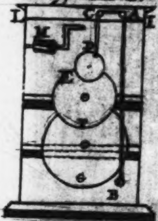


Fig. CXLVI.

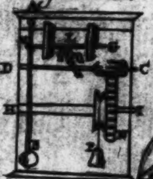


Fig. CXLVII.

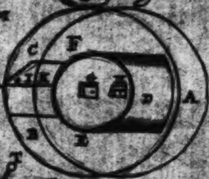


Fig. CLII.

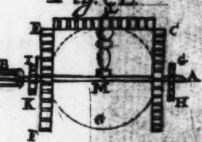


Fig. CL.

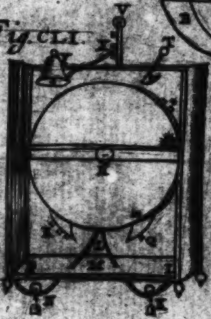


Fig. CLI.

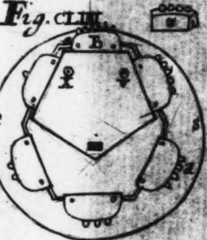


Fig. CLIII.

Fig. CLVIII.

LVII.

Fig. CLIX.

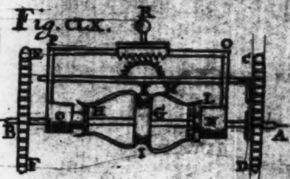


Fig. CLX.

Fig. CLXI.

Problem XXVI.

To procure excited Sounds at appointed times by many Artifices.

THis Father *Schottus* teaches at Propoſition the 25th. thus, incloſe a Steel ſpire with two little Wheels and a little Hammer, within a little bell, and this little Engin ſtands upon 3 or 4 feet, and hath a little tongue ſticking out downward, by which the ſteel ſpire being firſt bent, the motion is imparted to the little Hammer; If then the little Engin be placed above the Index of the clock lying Horizontally, or applied vertically about the centre of the Index, the feet of the little Engin being ſtabliſht, and that little tongue ſticking out, directed to the line of the hour which you deſire to excite, then the Index of the Clock being conveyed to the little tongue, and opening the incloſure of the little Hammer gives the ſtroke required; and after that whenſoever you pleaſe to remove it you may, and put it again to the little Engin.

Fig. 162. *Secondly*, if a Clock be required ſhewing only the hours, and to hang to the wall of a room; In the wall nigh which the weight of the Clock deſcends faſten in A a little arm, or Leaver A B, movable in A, on the end of the Leaver B, bind one end of a ſmall chord, than to a little Bar fixt in C caſt over the other end of the ſmall chord, to which bind a little ſpar or piece of a ſtick C D; laſtly, faſten a third little Bar in E, within which and the end D of the ſtick put the light ſtick E D between, ſo that it may ſtick faſt between the little bar E and the end D of the ſpar or piece of ſtick, and the weight G being hung will therefore ſtick faſt, under which you muſt put a braſs baſon, or ſuch like body of ſound, in which the weight G falling, excites a ſound; then lift up the weight F impelling the Clock, to ſo many hours as you deſire it to excite, for the weight E being ellapſt in a determined time, the ſtick being conveyed ſlowly to E D bares it down, and caſts it downwards: And this obſtacle being taken away, the ſtick C D being looſed ſends down with a force the weight G into the baſon underneath.

Thirdly, for excited ſounds for Souldiers, or Husbandmen, to a determined time, you may prepare them eaſily in this manner, take a piece of match, ſuch as Souldiers uſe, of one thickneſs and denſity every where, try diligently how much the fire will conſume of it in an hour, then allowing the length of the match for as many hours as you pleaſe, note the end, and extend the whole in length upon ſome piece of timber in an Horizontal ſite, and a little elevated from the earth: Then in the firſt ſign noted in the match, bind a little chord, and to the ſame ſome weight, *viz.* a ſtone, and the other end of the rope or chord bind about and make faſt to ſomewhat, as to a wall, or a tree, *&c.* for it will come to paſs, that when it hath burnt to the noted ſign, it burns or deſtroys that end of the little rope, and the ſtone falls into ſome Veſſel or table placed juſt under, it and ſo makes a noiſe.

Many other ſuch like may be thought on which may either be applied to Clocks, or may effect it themſelves, that at an appointed time they may waken and raiſe up them that ſleep by ſome noiſe; For in the firſt place all kind of Clocks which we have deſcribed before, to wit, which are moved in deſcending by an inclined plane, that may eaſily be done, if while they come to ſuch a line of the hour, they run againſt ſome obſtacle, from whoſe repulſe or removal, a ſound is made, or ſome other noiſe excited; *Secondly*, we may obtain it by all hour glaſſes of ſand or water, for being increaſed by degrees by the weight of the water or ſand falling down, it may be made, that when it increaſes to ſuch a magnitude the other weight ſhall prevail, which either lifts it up, or being freed from the Impediment it ſhall fall down, *&c.*

Problem XXVII.

Divers Ornaments applicable to Clocks, and ſuch like Engins.

THE Ornaments which may be added to Clocks, and other Chronometric Engins, are innumerable, for beſides thoſe which belong to their Indexes, and the other before mentioned, the ingenious Artificer may eaſily invent many other, ſome whereof we will ſhew briefly.

Firſt, a Clock may be made which not only declares the hours and quarters, but alſo the minutes and ſeconds, and that either with divers little bells, or by a muſical Inſtrument of Chords or Pipes.

Secondly, the noiſe of the foreſaid Harmony may be made, either before thoſe ſtrokes can publiſh the Muſical conſort, not only in ſmall bells, or any other Inſtrument, or alſo more together, which may eaſily be done by Phonotactic Cylinders, as is ſhewn before ; and not only by thoſe Cylinders, but alſo by an oblong plane, to wit, if you have a thick plate of mettal or a wooden table, to which faſten ſo many ſmall bolts, or pins, and diſtant a due proportion between themſelves as the Muſical tone requires, ſo that while that plane is moved upward and downward to the right hand, or to the left, his ſmall pins ſticking out, hits againſt the Organ, or other Inſtrument, &c. And this oblong plane may be moved here and there by a retrograde motion, as is ſaid before concerning the Index of the like plane at Problem. 17, in which caſe, notwithſtanding it behoves the whole thing to be doubled, to wit, one anſwering to one half of the oblong plate moved in one part, and the other to the other half in the return of the ſame plate.

That the Clock, or Inſtruments, may be rightly applied, the following things are to be obſerved. *Firſt*, the toothed Wheels of Clocks which the Cylinder turns about, ought to be ſcituate in the middle of the ſame Cylinder, or in both ends of it, for if it be applied to one end only, ſome inequality eaſily happens to the motion, by the reſiſtance of raiſing the Hammers,

mers, or depreſſing the little hands, *&c.* and the Cylinder muſt be exactly turned: *Secondly*, for each ſmall bell (if you will make the ſounds on bells) let there be two Hammers, two little hands, and two rows of holes in the Cylinder, to wit, that any note although ſhort in the tune, may be expreſt, when they are doubled, or repeated many times, for if thoſe notes be many, to wit, tailed or twice tailed following immediately, it cannot ſo well be ſtruck by one Hammer, and preſently raiſed. *Thirdly*, the fewneſs of holes for one touch, may be ſupplied by the diverſity of ſmall pins, more or leſs, ſtretched out without the hole in which they are faſtned: *Fourthly*, to greater Hammers, or greater reſiſtings of Elevation, Poiſers or weights muſt be hung as much as need requires; *Fifthly*, the little hands and ſmall pins, are moſt exactly of a length. *Sixthly*, for accelerating the motion of the Cylinder, thoſe wings which catch the wind, or ſmall weights inſtead of them, are movable, that they may be moved more or leſs to the Centre of motion. *Seventhly*, when the motion of the Cylinder acted by weights, is ſlower in the beginning, a ſtay muſt be put between, of one touch, or a touch and an half, to gain the Impetus, before the little keys or pins begin to publiſh the ſtrokes: *Eighthly*, if the Conſort of muſick preceed the ſtrokes of the hours, care muſt be taken that the key opening the ſtriking Wheel of the hour be movable, leſt when the tunes are ſome ſhorter than others, the ſtroke of the hour may be a long time expected.

Thirdly, as Indexes of Clocks, and other Engins, belong to the Senſe of the eyes, and of the ſound to the hearing, ſo to the ſame hour meaſurers, other ornaments may be added, which belong to Odour or ſmelling; for it may be made that every hour, or at other appointed times, a box or ſmall ciſtern may open, in which ſome odoriferous body ſmelling very ſweet is cloſe ſhut, and the Odour will diſperſe it ſelf into the whole room; in like manner cocks of ſmall fountains may be opened, ſending forth Odoriferous liquors, which liquors may be divers, according to the diverſity of the hours of the time; yea, they may be ſo fine and full of Spirituous rectification, that they may reſolve into air, and by their ſubtilty vaniſh, their Odour only remaining. Neither is it neceſſary to uſe many fountains or ſpirital Engins, if ſo be you make a ſmall Engin, out of whoſe cock only, divers liquors run forth every hour:

Alſo

Alſo Odours may be made either by means of perfuming fire which may be excited every hour, to wit, by percuſſion,that the next ſweetned matter may be burnt; Or being moved into an occult furnace, or lamp, the matter may be moved to them, or rather thoſe to it.

Fourthly, It may be made, that the clock every hour or appointed time, ſhall atchieve divers offices of truſt, as it were a ſervant, and be dilligent in the Bed-chamber deſigned to various Offices; ſo Cloks may be made which at a prefixt time of night ſhall ſtrike fire and kindle a light; and in the ſame manner they may be ſo fitted, that they may ſend forth water from a fountain, at certain hours for the waſhing of hands, or draw it from a well, or ſo as to ſnuff candles dexteriouſly, at appointed times: Alſo a clock may be made, which being placed on a Table, may repreſent *Bacchus* ſitting on a Tun, and at certain times fill pots with divers kinds of wines: Alſo a Statue may be made in the top of the Clock Turret, that may unfold a ſtreamer in the morning, and fold it up in the evening; and many other ſuch like as theſe may be performed.

Laſtly, other Inſtruments may be added to Clocks which may ſhew the degrees of heat and cold, and alſo of moiſture and dryneſs, or which ſhall foretel when it will be rain and when fair weather, yea, and they may ſhew the winds at any time in an incloſed chamber.

Problem XXVIII.

To make a Chariot, or ſhip, with an Index of Miles, for the meaſuring of a Journey.

Fig. 163. MEaſure the compaſs or Periphery of the Chariot Wheel propoſed, and for example let it be ten feet; To the Axis of this Wheel A B, fit a ſmall tooth E, running on another Wheel CD, furniſht with 50 teeth: Again this Axis I E muſt have a ſmall tooth, like to the ſmall tooth of the former Wheel in E, which folds into the teeth of the

the Wheel E F, divided into 12 equal parts, each of which consists of 10 teeth, so that all the teeth of this Wheel are 120; Moreover in its Centre G an immovable Index is disposed, which will tell the number of Miles and hundreds of Paces that hath passed by the Chariot in the Journey; for each circumvolution of the Wheel A B, that is, every two paces that is made in the Journey, one tooth of the Wheel C D is moved forward by means of the small tooth C, and therefore since the Wheel C D is furnisht with 50 teeth, its whole circumvolution will be compleated after 100 Paces, and then it moves forward the Wheel E F by means of the little tooth E; then since every part of division of the Wheel E F consists of 10 teeth, after every 10 circumvolutions of the Wheel C D; that is, after 1000 Paces, or one mile of the Journey, the Index after that will note another number of Miles; in the same manner altogether the thing may be done in a Ship, provided that a Jagged Wheel like to the Wheels of Mills be so fitted to the side of the Ship, that it may freely move about the axis, while its Jags hit against the water; and this Wheel will be instead of the Wheel of the Chariot A B, to which others are added, as we have said; for the whole Artifice consists in this, that the circumvolution of the first Wheel which answers the length of the Journey be multiplied proportionally to the other Wheels C D and E F, which may be done easily, and divers ways.

Problem XXIX.

The method of making Archimedes's *Screw for the raising of water several ways.*

Fig. 164. ARchimedes his Screw is no other than a Column, or Cylinder, on which a Tube is wound about spirally, or in the nature of a screw, as appears in the annexed Scheam, where A B represents the Cylinder in an inclined site to the Horizon, and C D shews the Tube drawn about it spirally; and this Tube if one end of it have an open mouth C, put in the water, so that the water enter into it, and then the Cylinder

Cylinder being duly inclined, and it being turn'd about by the two poles, or ends of the Axis E F that it ſtays upon, it will come to paſs that the water-ſerpent by little and little will aſcend to the top, and run out at the other mouth D.

This ancient and moſt ingenious Engin, owns the moſt Ingenious *Archimedes* for its inventer, which firſt uſed it to empty water out of the great ſhips of *Hiero*, King of *Syracuſe*; then the *Egyptians* uſed the ſame, (witneſs *Diodorus Siculus*) to draw out the water from the fields drowned by the River *Nyles*, and *Cardan* in his book *de Subtil*, makes mention of a Blackſmith that made this kind of Engin, and imagining himſelf to be the firſt inventor of it, for joy ran out of his wits.

How much the Cylinder, or its Axis E F, ought to be elevated above the Horizon is not eaſily determin'd, as will appear by what follows, although commonly Mechanics (with *Vitruvius*, Book 10, Chap. 11.) require ſuch an inclination as conſtitutes *Pythagoras* his triangle E G F, to wit, ſuch that the ſide or Baſe E F which reſembles the Axis of the Cylinder ſhall be to the ſide E G, which is the Horizontal line, as 5 to 4, and the ſide E G in which the other ſide F G falls perpendicularly, is to F G as 4 to 3.

And the Tube and its Spire muſt be ſo fitted about the Cylinder, that each Spire be more or leſs inclined, and more or leſs nearer each other by turns.

Beſides to the ſame Cylinder, (which may be greater or ſmaller) there may be put about, two, three, or more Tubes, ſo that one ſucceſſively after another may draw the water beneath, and may pour it out in the ſame order above.

Some hide the Tube, or Tubes, within the hollow of the Cylinder; or they make the whole cavity, except the Axis in the middle, into a Spiral pipe, or Channel, after the manner of winding ſtairs, for firſt they make the Channel ſpirally about the Axis of ſmall timber, then afterwards they cover the whole all over, that the whole Engin ſeems a meer Column, the myſtery lying hid within; Father *Chriſtopher Grumberger* made a tranſparent Channel, or ſpiral pipe, covering it over with a Selenite ſtone, or looking Glaſs, that it may appear to the eye looking on it, how the water aſcends.

If about the Cylinder you fit little boards ſuch as is uſed in mill Wheels, or a Wheel furniſht with little boards be fitted about the ſame, near the lower part B, this part may be ſo kept above the

water of the River flowing, that the little boards may be forced by the water, and turn about the Cylinder, for so the water may be conveyed from the River into a meadow, or any other place that you will have it.

Moreover you may raise water to any height in a narrow place, *viz.* within a Tower to the top thereof, as we have known done at *Augusta* in *Germany*; to wit, if the spiral pipes be multiplied, so that the water being raised by the lower spiral, and being poured out in D into some receptacle, or Cistern; hence it may be raised higher again by another Spiral, and so successively by more spirals, as high as you please, all which Spirals may be moved by one power, *viz.* by the water of a River underneath, or by another animated Power.

Thus much as to the making and common use of the Screw, or Spiral pipe, and you will scarce meet with any thing else among writers, but that which contains the reason wherefore the water ascends by the spiral pipe, contrary to its natural gravity, you will hear the same story among all of them that I have read; water indeed always descends in the spires of a Tube, and flows naturally to the lowest place, but nevertheless in the mean while by turning round of the Cylinder 'tis conveyed to a higher place; likewise the weight of the water it self, while it advances the spiral Tube, or pipe, helps its advancment: Some say 'tis done by a certain mixt motion joyn'd together, of the descent and ascent of heavy bodies, which while they affect to descend by their proper motion, they run through the Spiral of their own accord, and the spiral by the turning about of the screw, the weight running down leisurely, and obliquely and as it were by stealth, raises it up by degrees, I say, you will find these, and such like expressions, or meer words which sound altogether the same thing.

That we may therefore shew the true cause of this motion clearly and manifestly without ambiguous words, we must observe some Experiments approved by us.

First, Not only water, or other Liquor, may ascend by the Tube of the screw, but also one, or more Globes of any solid metallic matter,

Secondly, by how much greater swiftness the screw is turn'd about, not only a greater quantity of water ascends proportionally to the greater swiftness, as if the motion of the screw be doubly swifter, the quantity of the water will be doubly greater

greater, which in equal time will be poured out of the upper mouth of the Tube, but a much greater proportion, so that it may happen that the motion of the Cylinder about its axis being put double, the quantity and consequently the velocity of the water ascending is triple, or also quadruple, or quintuple; and this appears clearly, if instead of water we place Bullets, or small metallic globes in the channel of the screw; for it will come to pass sometimes, that the screw being turn'd about, the Globe will ascend but very little, or if it ascends a little, it presently slides or falls down again in the Tube, but the velocity of turning about being increast, it only ascends, all the other circumstances remaining the same.

Thirdly, the lesser the axis of the screw is elevated from the Horizon, the greater plenty of water ascends, and with more ease, so that the screw be turn'd with the same velocity, and all other things alike.

Fourthly, There is not the same proportion of quantity of water ascending through a narrow Tube of a screw, to the quantity of water ascending through another broader Tube, as is the Basis of the narrow Tube to the Basis of the broader Tube; for example, let the narrower Tube be A, and the Tube B doubly broader (or as broad again,) I say, through the Tube B there does not ascend a double quantity of water the other things being alike, but less then double, and therefore if there should be two Tubes of A, and only one Tube of B, although the largeness of this, or the inward cavity be equal to the double largeness of the other two Tubes, notwithstanding it will not draw an equal quantity of water, so that they are all of an equal length, and in the same manner alike, or the screws are turn'd alike.

These things being noted, I say, in the first place, that 'tis false which they commonly affirm (as is said before) that the water does descend in any manner in the Tube of the screw, and much less to make a mixt motion by the ascent and descent: And this appears in the first place chiefly by an experiment of a Globe turn'd about in a Cylinder through a glass Tube, so always ascending as 'tis never discern'd to descend (I speak in respect of the Tube) for it runs towards the upper part of the Tube, never going back untill at length it break out at the upper mouth of the Tube; the same which appears in the upper

superficies of water aſcending; and certainly it ſeems to be implied in the terms that the ſame heavy body ſhould aſcend and deſcend together at the ſame time, for it will be moved together with two oppoſite motions, which is contrary, as we have ſhewn before.

The reaſon then why the water, or Globe, or any other heavy body, aſcends through the ſpiral Tube of the ſcrew, ought to be ſought from the adherence of the water, or other body, to the inward ſuperficies of the Tube, either from ſome roughneſs of the ſame ſuperficies, or alſo of the ſolid Globe aſcending, by reaſon of which the motion of bodies is hindred in their deſcent by an inclined plane, which how it happens in the ſcrew will be eaſy to explain from what is ſaid.

I ſay, then the water, or Globe, doth not always move in the Tube, ſo as always to go forward further, but by ſome little ſpace of time, wherein the Cylinder is turn'd about, the Globe reſts in the ſame part of the Tube; but becauſe the ſame time, in which the Globe reſts with reſpect to the Tube, that part of the Tube on which the Globe reſts, aſcends by the turning about of the whole Cylinder, it comes to paſs alſo, that the Globe reſting in that part, in the mean while is raiſed higher from the Horizon, and the other parts of the Tube immediately following, obtain a lower ſite with reſpect to the Globe, which therefore are conſtituted in a plane ſomewhat inclined; then the reſt of the Globe ceaſing in that part of the Tube, it deſcends by that inclined plane to the lower part, and there it reſts again (for as much as if it ſhould paſs further, it ought to aſcend, which is contrary to its natural gravity) and while it reſts in that part, 'tis transfer'd again together with the Tube into an higher ſite, from whence it again roles down by another inclined plane on the other part of the Tube; and ſo by degrees is moved forward even to the upper mouth of the Tube; and the reaſon of this interrupted motion, or interpoſition of reſt, is, as I ſaid, the adherence or roughneſs of the ſuperficies both of the Tube and alſo of the Globe; for it comes to paſs that by ſome little ſtays the motion is intermitted, while the movable body finds reſiſtance in the rough plane.

Fig. 165. And there is another reaſon beſides the foreſaid reſiſtance of Roughneſs, or adherency of bodies, which very much moves forward ſuch motion: to wit, the impreſt Im-

petus

petus of motion in the oppoſite part of the Globe,or water. Let the Horizontal line be A B, above which the axis of the ſcrew A C is raiſed, and let the ſpiral Tube be D E I L M N. Now, for example, if the Globe of lead be in part of the Tube E, and the Cylinder be turn'd about with a motion from E towards G D; while the Globe reſts a little in part of the Tube E, in as much as that part together with the Globe reſting is raiſed by the turning about of the Cylinder into a place nearer the horizontal line, *viz.* into P, and in the mean while, the part of the Tube H is depreſſed to Q; from whence it comes to paſs that part of the Tube is conſtituted in the inclined ſite P Q, and therefore the Globe, which was found in P deſcends through that part of the Tube, or inclined plane from P in Q, where you ſee now the Globe advanced higher above the Horizon; for the point Q is more diſtant from the Horizon A B, than the point E, where the Globe was before; again in Q, becauſe of ſome reſiſtance which it cannot over come through the little ſtay of time reſting, 'tis raiſed as before with part of the Tube in the ſame point Q, then anſwering to the time, from whence again after reſting, it falls down in the other part of the Tube, and ſo ſucceſſively in deſcending it truly aſcends, but not ſo as to aſcend in the ſame time in which it deſcends, and therefore it cannot be ſaid, truly ſpeaking, that it aſcends in deſcending, nor that that motion is properly compoſed of aſcent and deſcent. Wherefore it aſcends in that part of time in which 'tis hindred by the adherence to the inward ſuperficies of the Tube, or its roughneſs, that 'tis not moved forthwith, but it deſcends after that ſmall ſtay, or little reſt, and becauſe it deſcends more oblique than before it aſcended, therefore the deſcent is leſs, conſider'd abſolutely and in a perpendicular line than is the aſcent; and therefore after all the deſcents it will be found higher above the Horizontal line.

Add, that after each deſcent, to wit, after the deſcent from G in E, it doth not preſently reſt in the loweſt place E, due to it naturally, but by the acquired impetus in deſcending by the inclined plane G E, it aſcends alſo further, *viz.* to H, eſpecially ſince the point of the tube H deſcends in the mean while,and paſſes away the globe, that therefore it may ſhun the ſteepneſs from E in H, by being ſucceſſively lighter, and aſcend eaſier.

Finally,

Finally, to the facillitating of this motion of the globe the imprest Impetus of the tube concurs to the opposite part of the motion of the globe, for it is found by experience, that the Globe descends more swift on an inclined plane, being moved (for example) from the East towards the West, if in the mean while that it descends, the inclination remaining the same, the plane be transfer'd by an opposite motion, to wit, from the West towards the East; since therefore while the Globe descends, by the inclined part of the Tube from G in E, or also while it ascends further from E in H, the Tube by the Circumvolution is moved by an opposite motion from H towards E and G, it come to pass from such motion, or from the opposite Impetus of the Tube, it acquires a greater velocity: But likewise this must be observed, that as often as the opposite Impetus of the Tube, or of the inclined plane avails to the velocity of the motion of the globe, so often the Globe suffers some rubing or wearing with the plane that lies under it: Wherefore from the beginning to the end, all the reason of the motion of the Globe in the spiral Tube of the screw, seems to be founded on the foresaid adherence, or resistance of bodies in the contact of superficies. And what we have said concerning the Globe, the same may altogether be said of water, or of any other body, notwithstanding we have made use of the Globe, in the example, because if the experiment be made, as we have oftentimes done in it, all these things clearly appear, which hitherto we have said; And that the Globe may be manifest to the eye, and the reason of its motion may be observed, either we must make use of a glass Tube, or the secret hollow channel about the Cylinder must be of transparent stone to see through; or you may easily put a double wyre about the spiral Cylinder, so that that Iron thred, or wyre, touch not the Cylinder, but stand above it about half an Inch, and the same distance also between it self, and therefore some quadrangles intercept the space of way, on which the Globe is placed as it were on a channel, or groove.

From what hath been said 'tis manifest, in the first place, how the motion of bodies which are raised by means of this Engin, are reduced to motion by an inclined plane.

Secondly,

Secondly, a reason appears why the turning the Cylinder about with a greater velocity, or more swiftly, that it doth not only raise greater plenty of water proportionally, but also makes the same ascent more abundantly easy; for since the opposite motion of the Tube avails much to the ascent of the water, as we have said, by how much swifter this motion is, which is made by turning about of the Cylinder, by so much the more the ascent of the water is advanced.

Add, that that little space of time which the water or the Globe rests in some lower part of the Tube 'tis raised higher, that therefore the rest ceasing it ought to descend less, and after the descent 'tis now much higher raised above the Horizon than before: moreover, since that little stay of the Globe happens from the impediment, or roughness of the Tube, suppose the Globe to be in E, and some impediment or roughness in the Superficies of the Tube, to be in its way on the part towards H; when this kind of roughness is moved forward towards P or G, and let that which raises the Globe be as far as P, if the Tube be moved more swiftly, it impresses a greater Impetus, and raises it higher.

Thirdly, 'tis manifest also, why if the screw be less elevated above the Horizon, that the water ascends the easier, I say, the easier, that is, with less force and labour of him, or that which turns the Cylinder: (for if the Cylinder being turn'd about with the same swiftness, an equal quantity of water should ascend, whether it be more or less inclinded) the reason is manifold: First, because when the Axes A C are more Elevated the weight gravitates more upon the prop of the Axis in A, but less upon the prop in C, but if the Axis be less raised above the Horizon, or comes nearer to an Horizontal site, the whole weight is distributed to the Props A and C with less inequality, from whence it comes to pass that the Circumvolution or turning about is easier. *Secondly*, and chiefly because the entrance of the water into the Tube by the lower mouth D, resists and strives against the weight or pressure of the water which is in the whole Tube, and that weight or force of pressure is not computed from the quantity of water which is in the Tube (for that is always the same whether the Cylinder be more or less inclined) but 'tis computed from the greater or lesser perpendicular CB; therefore when the perpendicular CB is greater, the water existing within the Tube presses more, and resists more the

enter-

enterance of the water by the mouth D, since therefore that force or pressure ought to be overcome by the power turning the Cylinder, as often as the mouth D draws new water, it appears why the screw being elevated higher is moved with more difficulty: Hence you may be satisfied that 'tis false that some say, that water therefore ascends easier by a screw less elevated, because the way and acclivity of motion is lesser, as if water in ascending by a plane more steep is also more wearied, which is foolish: Hence also it is, that a solid Globe is elevated almost with equal facility through the Tube of the screw, whether the Cylinder be more or less inclin'd; for in this case each reason aforesaid ceases, and the second reason ceases wholly, since in each circumvolution of the Cylinder a new Globe is not raised, but that only which is moved forward in the Tube: And the first reason also hath scarce any room, if we suppose the Cylinder alone not to gravitate much upon the Prop or stay on which the ends of the axis rest upon.

And from hence it appears why it cannot be determined, how much the inclination of the Cylinder ought to be elevated above the Horizon; for this ought to be consider'd not absolutely, but with respect to many other things, and chiefly to these three, to wit, to the velocity whereby the Cylinder is turn'd about; for if it be turn'd about more swiftly it may be more elevated, and neverthelesss the water will ascend through the tube. Secondly, to the greater or lesser adherence of the water, or other Liquor, to the inward superficies of the spiral tube; for when this adherence is greater, the water doth less gravitate upon the lower mouth of the Tube, and besides it more easily contains the Impetus from the motion of the Tube in that manner which is shewn a little before. Thirdly, and chiefly to the obliquity of the winding compass of the Tube, for if the spiral or winding compasses be thicker and closer together, and more near each to other, the Tube will be longer, and therefore the way and motion of the water longer before it comes to the upper part of the Tube, but neverthelesss by reason of the greater obliquity of the spiral, the lower water gravitates less, and ascends easier, and therefore the Cylinder may be raised higher above the Horizon.

According to the variety therefore of these circumstances the inclination of the Screw may be varied: Notwithstanding this universal precept must be observed, to wit, that the Cylinder

A C be never elevated above C, to ſuch an height, that the ſpiral of the Tube DE or IL or MN appear parallel to the Horizon AB; for the point of the Tube D ought to be higher than E, and the point I higher than L, and ſo of the reſt; otherwiſe the water being in part of the Tube D E, will flow out at the mouth D before it be moved forward any further in the Tube.

Fourthly, from what is ſaid, that queſtion may be reſolved, to wit, whether or no 'tis moſt convenient to have one large Tube to turn round with the Cylinder, or many ſmall ones: Father *Grymberger* affirms, that if one ſpiral Tube circumſcribe the whole Cylinder, ſuch a ſimple ſcrew will pour out as much water, as if there were many Tubes, and ſomewhat more, and he aſſignes this reaſon, becauſe many ſpirals of a Tube by reaſon of their thickneſs which they muſt have ought to occupy more room in a Cylinder than the thickneſs of one. But although this be moſt true, yet our queſtion is not whether more water may aſcend by one Tube only than by more; for example, unleſs three Tubes taken together are equal to one other larger Tube, 'tis certain that greater plenty of water may aſcend by that one larger Tube; but the queſtion is, whether or no ſuppoſing that thoſe three Tubes be exactly equal to the Capacity of one larger Tube, and let the Cylinder be capable, that is fitted either to the three ſmall Tubes, or to the other larger one, I ſay, 'tis to be conſider'd, whether to make uſe of the one large one, or thoſe three ſmall ones?

And to this Queſtion I anſwer, It would be better to uſe three ſmall Tubes (ſo that they do not gravitate more by their weight on the prop ſuſtaining the Cylinder) than one larger; and not only becauſe (as we have ſaid appears) in the foreſaid experiment) that they raiſe more water; but likewiſe becauſe it aſcends eaſier, and with leſs ſtrength of the power moving the Engin. The reaſon is, becauſe although the three Baſes of the leſſer Tubes be equal to one Baſe of the larger Tube, and they are ſuppoſed all of an equal height, nevertheleſs it gravitates or preſſes leſs in the triple baſe, or in the lower mouth of the ſmaller Tubes, than the water gravitates in one baſe only, or in the mouth of the larger Tube, and that therefore becauſe although the Capacity of the three Tubes be equal to the Capacity of the one Tube, nevertheleſs

the inward superficies of the three Tubes is at least doubly greater the inward superficics of the one larger Tube, and since the adherence of the water is greater where the superficies is greater to which it adheres, and since it ascends easier and gravitates less upon the base when the adherence is greater, it appears to gravitate less on the bases of the three Tubes, and in them the water ascends more easily. I add also, that the water is easier drawn if it be drawn successively by many Tubes by one circumvolution of the Cylinder, than if the whole be drawn with one turn by one Tube.

From the foresaid greater adherence of the water of the smaller Tubes it comes to pass also, that although the Cylinder be turn'd about with less swiftness, yet the weight of the water cannot so easily overcome that adherence and fall back again downward, as happens in wider Tubes, which unless they are moved swiftly the water by its weight easily goes back more.

Hence also we esteem it a thing not altogether impossible to to make a screw with such artifice, that by means thereof the perpetual motion may be obtain'd, for the ascent of water or of other heavy bodies seems easiest of all by the screw.

And that this motion may be rendered yet easier, some ingenious things occur to my mind which I believe may be made use of with some profit.

The first is, when you put one or rather more Tubes about a Cylinder, within each of which you may put cotten thred, extended from one end to the other; for by this means the adherence of the water increases, and creeps along more easily through the Tubes, although the quantity be less, all one as if one large Tube were divided into many small ones.

Fig. 166. The Second is, since the rubing or wearing of the Poles of the Axis on the Prop or stay on which they rest, is the chief impediment of all, to the Circumvolution of the Cylinder, and since there is a greater rubing and resistance on the lower Prop A, by the greater gravitation there than in B, the rubing may be hinder'd, if not wholly, at least in great part, by affixing a Wheel, or rather a Tympane C D, to the lower part E of the Cylinder A B, which Tympane must be hollowed within or void, not only the lower part D, by reason of its lightness will swim upon the water, but also it will sustain the

Cylinder, ſo that its Pole A within the notch of the Prop may be turn'd about without any reſiſtance.

Fig. 167. The third is, that the Cylinder be made of light matter, for the lighter it is the eaſier 'tis turn'd; wherefore it will be ſufficient to fit the Tubes ſo, and to turn them about in Spirals, that they will need no Cylinder to ſuſtain them; for it will be ſufficient if in the extream heads of the Tubes, you fit two little Wheels A B, C D with their Axes fixed in the Centers. For unleſs they be very big and large, and the Cylinder very long, they cannot eaſily be bent by the water, or by their proper weight, and eſpecially if they are made of rough matter, *viz.* of thin Iron plates cover'd over with Tin or Glaſs, *&c.* Or if you fear the bending of the Tubes, you may fit here and there in ſtead of the whole Cylinder, two or three rulers extended according to the length from A to C, and from B to D, which rules or Spears ſupport the Tubes, leaſt they bend in the middle. Likewiſe you may ſo turn about many ſmall Tubes ſpirally, one immediately near to another, that they being all united together, make one whole Cylinder, or rather a Tube, which reſembles a Cylinder made hollow within.

Fourthly, If you deſire to raiſe not Water but a ſolid Globe by a Pulley, you need not make uſe of a Tube; two iron wyers turned about ſpirally parallel to each other, and faſtned to the extream heads in the Circumference of the little wheels A B and C D, will be fit for that purpoſe; and thoſe wyers ought to be ſomewhat leſs diſtant from one another, than the thickneſs or diameter of the Globe; for ſo the Globe will be detain'd within each wyer always in the lower parts of the ſpirals, and will aſcend by degrees by thoſe ſpirals being turn'd about.

Fig. 168. Alſo it may be made of two thin plates of Mettal, or of one only made hollow after the manner of a Channel or Groove; yea, we have made a ſcrew fit to take up a leaden Globe or Ball of an inch Diameter, of thick paper or paſtboard turn'd about ſpirally, to wit, the Tube of them which compoſe a Telleſcope we have cut ſpirally, ſo that the Globe is detain'd within the ſpiral cleft, and will aſcend by the ſame cleft, the Tube being turn'd about. Moreover one plate of mettal only may be turn'd about a Cylinder which aſcends ſpirally, and ſticks out every where above the ſuperficies of the Cylinder

one or more inches, according as the magnitude of the Globe to be raised requires, and the plate must be of such a breadth, as is the Diameter of the Globe, or a little more, and erected perpendicularly upon the superficies of the Cylinder, and one of its sides fastned to the same Cylinder; then the Cylinder being elevated in an oblique site to the Horizon; for Example, in the site A B, and the Axis leaning or staying upon its prop, the hollow plate of mettal D C is fitted under the Cylinder, which remains unmoveable in the same oblique site, and then being distant a little from the spiral plate, so that as it were, it is razed by the subjected channel or hollow plate being turn'd about. Then if you place a Globe on this, and turn about the Cylinder, the spiral will move forward the Globe by that inclined Channel from D in E, and from E to F, *&c.*

The same power or strength must be applied here, as a screw hath to raise water, or another body, of which we have spoken elsewhere concerning the common Screw; for as you see the motion or elevation of weight by this screw of *Archimedes*, is indeed a motion by an inclined plane, where that universal principle always takes place, that the increase of force is taken from the proportion of the velocity of the power moving, to the velocity of the weight moved; wherefore, if for example, as in the present figure the spiral being four times turn'd about, the Cylinder be 12 feet, and the Globe ascend from D to F, in the plane or inclined Channel D C two feet, the power as 2 may raise the weight as 12.

What we have said hitherto concerning a Cylindric screw, may also be understood of a Conic screw, for instead of a Cylinder we may use a Cone to which the Tube may be spirally turn'd about, as is commonly known. And although some prefer a Cone before a Cylinder, yet we see not any effect that it performs better; therefore since a Cylindric screw is easier prepared, we may use the same most safely, and perhaps most profitably, at least in many cases.

Many other things occur which may be said concerning this Engin, which in our opinion are very Ingenious, for writers have scarcely shewn any thing worthy of consideration to Posterity in this matter although it be very capacious, as may be easily understood from those things which we have briefly shewn, with which we shall conclude this ninth and last Book

of

of *Mechanick Powers.* Giving all honour and Praiſe to that great Maſter of Arts, and Fountain of all Wiſdom, the Omnipotent God Bleſſed for evermore.

I had here put an end to *Mechanick Powers*, but meeting with ſome new inventions relating thereto, lately publiſht in *France* by an able *Mathematician*, which if put in practice may be uſeful and beneficial in Engins; I thought fit to add them by way of Appendix, and they are theſe that follow.

APPENDIX.

BOOK X.

Of Epicycloids, *and their uſe in* Mechanicks.

Definitions.

Fig. 169. IF the circle ABD be rouled or turn'd about upon the arch A *b d* of any Circle, the point D which is the extream or end of the Diameter A D, will by its motion deſcribe the Line D 14, 15, 16, 17 *d*, which is called an *Epicycloid.*

The circle A B D is called the generating circle of the *Epicycloid.*

The arch A *b d* is the Baſe of the *Epicycloid.*

If the generating circle roul on the out ſide of the circle of the Baſe, the *Epicycloid* is called *Exterior*, or *Outer* : But if the generating circle roul on the inſide of the circle, the *Epicycloid* is called *Interior*, or *Inner.*

The ſpace contain'd by the *Epicycloid*, and by its Baſe, is called *the ſpace of the Epicycloid.*

The

The Dimension of the Space of the Epicycloid.

Lemma 1.

Fig. 170. LET the Semicircle be A P *p* B, whose diameter is A B, and its centre K; having drawn the line P *p* Parallel to A B, and meeting the circle in the points P *p*, from any point C of the diameter A B drawn longer, draw the lines C P, C *p*;

I say, the sum of the right lines C A, C P, is to the sum of the right lines C B, C *p*, as the difference of the right lines C B, C *p* is to the difference of the right lines C A, C P; or else, which is the same thing, the Rectangle made of the sum of the lines C A, C P and their difference, is equal to the rectangle made of the sum of the lines C B, C *p* and their difference.

Lemma 2.

Fig. 171. In the Triangle C A V if the right lines P X, *p* G, B M being parallels to the base A V, cut the side C A, so that the sum of C A and C P, be to the sum of C *p*, C B, as the difference B *p* the Segment of the last, is to the difference P A of the first.

I say, that the Trapezias M *p*, A X are equal between themselves.

Lemma 3.

Fig. 172. Let the Semicircle be A D E B, and on its diameter A B prolonged or not prolonged, let the point C be taken, and draw any right line D E Parallel to the diameter A B which meets with or touches the circle in the points D, E; From the Centre C, with the Semidiameters C A, C D, C E, C B, describe the arches of circles A F, D P G, E *p* H, B I, which meet with any right line as C F drawn from the centre C, in the points F, G, H, I.

I say, that the foursided mixt figures A F G P, *p* H I B are equal between themselves.

Demon-

Demonstration.

Make the right line A *f* equal to the arch A F, which must make with the diameter C A, the right angle C A *f*; having drawn C *f*, draw also the right lines P *g*, *p h*, B *i*, parallel to A *f*.

'Tis evident by construction that the triangle C A *f* is equal to the Sector C A F: In like manner, the Triangle C P *g* is equal to the sector C P G, wherefore if from the equals C A *f*, C A F, you take away the equals C P *g*, C P G, the remain will be equal, to wit, the Trapezia A P *g f*, and the four sided mixt figure A P G F. We may demonstrate in the same manner that the Trapezia *p h i* B, is equal to the mixt figure *p* H I B.

But by the first *Lemma* the sum of the right lines C A, C P, is to the sum of the right lines C *p*, C B, as the difference of C *p*, C B which is *p* B, is to the difference of C A, C P, which is A P; wherefore by the 2d. *Lemma* the Trapezia A *f g p* will be equal to the Trapezia *p h i* B, and the mixt figures A F G P, *p* H I B which are equal to the Trapezias are also equal between themselves.

Lemma. 4.

Fig. 173. If the circumference of the Semicircle A B D be divided into equal parts between themselves in the points E F G B H I, *&c.* and the number of these parts be even and indefinite, and on the diameter A D prolonged or not prolonged you draw from the point Y as a centre the arches of a circle, whose radius's are the distances Y A, Y E, Y F, Y G, *&c.* and let the length of the arch A *d* described by the point A be equal to the circumference of the Semicircle A B D, and let the Arch A *d* be divided into as many equal parts *e f g h* as is in the Semicircle A B D: Then having drawn the Radÿ from the centre Y to the divisions *e f g b h*, &c. then you will have the mixt four sided figure A D X *d* divided into an indefinite number of little mixt four sided figures which will have the following properties.

Because the equal divisions of the Semicircle may be drawn by the points of division of the right lines K E, I F, H G, *&c.* which will be parallel to the diameter D A of the circle; therefore by the 3d. *Lemma* the four sided figures *d y* R *k*, X *z a* 4, will be equal between themselves being equally removed

moved from the extreams: But also those which are contain'd between the same circles will be equal between themselves, because of the equal divisions of the arch A *b d*; wherefore the 4 sided figure A *e* E *r* will be equal to the 4 sided figure X *z a* 4.

We may demonstrate in the same manner that the 4 sided figure 2 X 4 *t* is equal to the 4 sided figure *d* 3 *f k* or A *e* 18 *q*, and so of the rest.

'Tis evident in each Sector, as Y X 4 or Y *d k*, that the four sided figures are equally removed from the extreams, as 2 X and 3 *u* are also equal between themselves; for the 4 sided figures X *x* and *d u* are equal, the 4 sided figures X *t* and *d s* are also equal by the foregoing *Lemma*: Wherefore if the greater be taken from the lesser, the remains which is the 4 sided figures 2 x and 3 *u* will be equal, and so of the rest.

Lemma. 5.

The same things being put as before and in the same figures, if you draw the diagonal line D L M N O *d*, compounded of an indefinite number of small right lines, which in the 4 sided figure A D X *d*, divides in two diagonal wise all the small 4 sided figures, which are in the diagonal from the angle D even to *d*, as appears in the figure, by the lines D L, L M, M N, N O, *&c.*

I say, that the 4 sided figure A D X *d* is divided in two, equally by the diagonal D O *d*,

'Tis not difficult at all in this place, to grant that the small diagonals which are from right lines, divide in two equally their particular quadrilaters, or 4 sided figures, and that the difference which is between the true division and this, is not found considerable, and seeing we may always find a less magnitude than any given, because that the quadrilaters which are divided, are supposed indefinitely small as is commonly accepted in the use of Indivisibles.

Now by that which is demonstrated in the precedent *Lemma*, 'tis evident that the Quadrilater A L is equal to the quadrilater X R; In like manner the Quadrilater *e* M is equal to the Quadrilater 4 Q; the Quadrilater *f* N equal to the Quadrilater 5 P, and so of the rest.

Where-

Wherefore all the like Quadrilaters together on one side of the Diagonal D L M N O P, &c. will be equal to all the Quadrilaters on the other side. But the line D L N O P d which divides diagonal wise all the small Quadrilaters which are in the diagonal, is supposed to divide also in two equally all those quadrilaters; therefore this diagonal, which may be consider'd as a crooked line, divides equally in two all the great Quadrilater A D X d; which was to be Demonstrated.

Scholium.

If we suppose that the point Y which is taken on the diameter A D is infinitely lengthned from the circle A B D, there may be right lines perpendicular to the Diameter A D, in stead of the Arches of circles, which pass through the points D K I H A, of which A d is one, which is put equal to the circumference of the Semicircle A B D, and which is divided into so many equal parts, as is the Circumference A B D; and lastly, instead of the mixt Quadrilaters, or 4 sided figures, as those before, you will have Parallelograms, which being equally removed from the Extreams, will be equal between themselves, and thence it follows likewise that the diagonal which divides diagonal wise all the little Parallelograms, which are from one angle to the other, will divide the whole great Parallelogram into two equally.

Lemma 6.

Fig. 169. The same things being put as before, if you make the Semicircle A B D to set forward, so that the diameter A D be placed on the part *e* 8 of the Radius Y 8 *e*, and that the point A agree with the point *e*; 'tis evident that the point *l* of the diameter will agree, or be in the point L of the Radius Y *e*; Moreover if we make it to pass even to the Radius Y *f*, and that the point A fall on the point *f*, the whole diameter A D will agree with the right line *f* 9, the point *m* of the diameter of the circle A D B will agree with the point M, and so of the rest: Whence 'tis evident, that all the points of the diameter A D, as D *l m n*, &c. describe the diagonal line D L M N *d*.

Demonstration.

But if instead of removing the circle A B D, we concieve it to roul on the base A *b d*; when the point E of the circle is come to *e*, the diameter of the circle E 10, will be joyned with the right line *e* 8, for by the Hypothesis the arches A E, A *e* are equal in length; and from the same, when the point F is come to *f*, the diameter F 11 will be joyned to the diameter *f* 9, and so of the rest. But if you mark the distances A *l*, A *m*, A *n*, on every diameter, as E 12, F 13, &c. it is evident, that while the circle A B D rouls on the base A *b d*, the points *l m n 7 p q* of every diameter meet one another in the diagonal line D M N O P *d*: For when the point A of the circle is come to *e*, the point 12 on the diameter E 10 will be in L, because that the distances 10, 12, D *l* are equal; and by the same reason the point 13, will be in M, &c.

But moreover, when E 10 is placed on *e* 8, and the point 12 on the point L, the point D of the circle A B D will be in the point 14 on the arch *l* 14 *z*: For the Semicircle 8, 14, *e* represents the Semicircle E D 10; and as the arch 10 D is equal to the arch D K by Construction, when the point 10 by the movement of the circle is come to the point 8, the point D will of necessity be on the point 14 in the arch L K L 14 *z*; so that the portion L 14 of this arch will be equal to the Portion L K of the same arch: In like manner, when the point 11 is come to the point 9, the same point D will be on the point 15 in the arch *m l* M 15, so that the arch M 15 will be equal to the arch *m l*, &c.

PROPOS. I.

Fig. 169. IN the precedent Figures 'tis demonstrated that the space of the moiety, or half of the *Epicycloid*, A *b d* 17, 16, 15, D, is equal to the half of the Quadrilater A *b d* X D, joined to the generating semicircle A B D.

Fig. 173. I have shewn before that the line D M O Q *d* divides the mixt quadrilater A *b d* X D in two equally, it remains then to demonstrate that the space D L O Q *d* 17, 16, 15, D, contained by the line D M O Q *d*, and by the half of the *Epicycloid* D, 15, 16, 17, *d*, is equal to the generating semicircle D B A.

By construction, the whole generating semicircle is divided into mixt Quadrilaters, as *m l* 11 *n*, and into two trilined, or 3 lined

Fig. CLXII.

Fig. CXV.

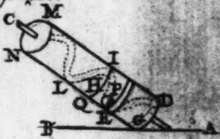


Fig. CLXIX.

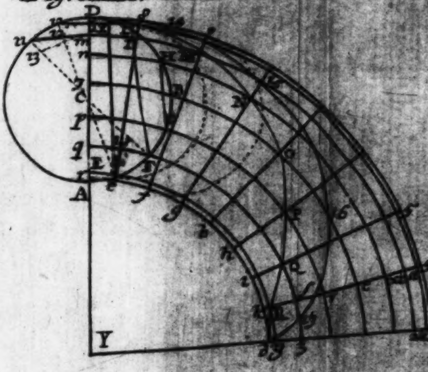
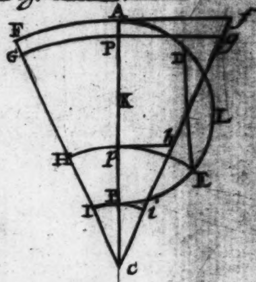


Fig. CLXXII.



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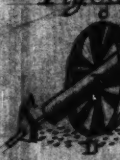


Fig. CLXIII.

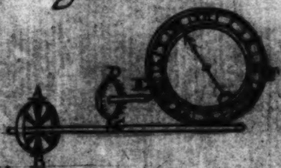


Fig. CLXIV.

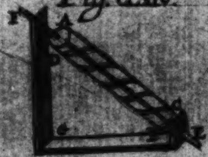


Fig. CLXVI.

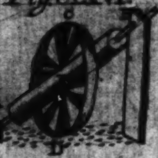


Fig. CLXVII.

Fig. CLXVIII.

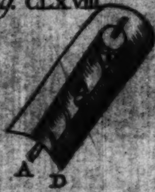
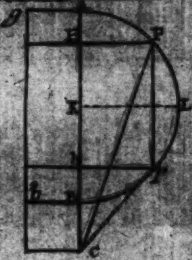


Fig. CLXX.



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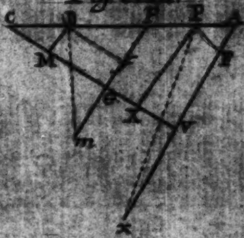
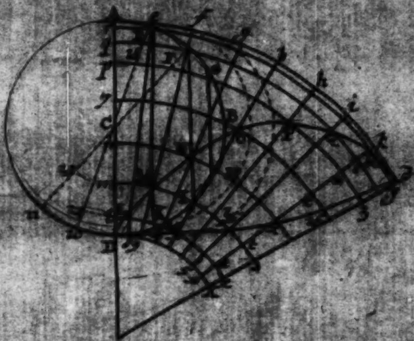
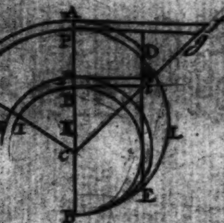


Fig. CLXXIII.





3 lined figures D K *l*, *r* E A: But alſo the ſpace D M O Q *d* 17, 16, 15, 14, D, is divided by the ſame circles deſcribed from the centre Y, into ſo many 4 ſided, and 3 ſided (or 3 lined) figures, as are in the generating ſemicircle; ſo that the arches of every circle contains ſo much in the generating circle which in the ſpace are equal between themſelves, as the arch M 15 in the ſpace is equal to the arch M *l* in the ſemicircle, which is evident by the formation of the *Epicycloid*: Wherefore the mixt Quadrilater, as L 14 15 M in the ſpace is equal to the mixt quadrilater L K *l m* in the ſemicircle, for they have the ſame breadth, and are incloſed in equal arches: But each of theſe Quadrilaters equal in the circle and in the ſpace being conſider'd as Indiviſibles of the one and the other, it will follow that the ſpace will be equal to the ſemicircle, which was to be demonſtrated.

Scholium.

Keeping to the ſame Demonſtration, if we ſuppoſe that the point Y is infinitely removed from the baſe A *d*, which baſe is a right line in this caſe, and the Quadrilater A *d* X D is a rectangle, which is then equal to the generating ſemicircle A B D taken 4 times, as appears by its generation: Wherefore the ſpace A *b d* 17, 16, 15, D, will be equal to the ſemicircle A B D, taken twice together with the ſame ſemicircle which is equal to a ſemicircle taken 3 times; the line *d* 16 D in this caſe is called *Cycloid*, or *Trochoide*, and ſometimes a little wheel.

PROPOS. II.

THe ſpace of the outer *Epicycloid* is to its generating circle, as 3 times the diameter of the circle which is the baſe, together with 2 times the diameter of the generating circle to the diameter of the circle of the baſe.

But the ſpace of the inner *Epicycloid* is to its generating circle, as 3 times the diameter of the circle which is the baſe, leſs 2 times the diameter of the generating circle, to the diameter of the circle, which is the baſe.

The Dimension of the Lines of Epicycloids.

Of the touching of Epicycloids.

Lemma I.

Fig. 174. Let the circles be E B F, F H which touch each other outwardly in F. Having join'd the centres K C by the right line E K C which passes by the point of contact, or touching F; from the extream E of the diameter F E, draw a right line E B, prolonged to the other circle in H.

I say, that the arch F H is greater in length than the arch FB.

Lemma 2.

Let the 2 circles be E B F, F H I, which touch each other in F, from the centre K of one of the circles draw the line K B I, meeting them both in B and in I.

I say, that the arch F H I is greater in length than the arch F B.

PROPOS. I.
Problem.

To find the point of Contact, or touching of the outer Epicycloid.

Fig. 175. Let the outer *Epicycloid* be G H M, whose base is the circle G A, described from the centre C. And let the generating circle I H A D of the *Epicycloid* be placed in such manner, that the describing point H be on the *Epicycloid* in that point in which the touching is made: If by the centre C of the circle of the base, and by the centre O of the generating circle you draw the right line C A O I, and by the extream I of the diameter A I you draw the right line I H to the point H.

I say, the right line I H touches the *Epicycloid* in the point H.

Lemma 3.

Fig. 176. Let the two circles be F A E, F R D which touch each other in F, having their convexities of the same side, and that the centre C of the circle F R D be out of the diameter F E of the circle F A E; having drawn a right line E A D from the extream or end E of the diameter F E, which cuts the circle F A E in the point A, and the circle F R D in the point D.

I say,

I ſay, that the arch F R D is more in length than the arch F A.

Lemma 4.

Fig. 177. Let the two circles be F S, F R which touch in F, and that have the convex parts of the ſame ſide, and let the centre C of the greater be on the diameter of the leſſer lengthned; if you draw the line C R D from the centre C which cuts the 2 circles in R and D.

I ſay, that the arch F R of the leſſer is greater in length than the arch F D of the greater.

PROPOS. II.

To find the touching of the inner Epicycloid.

An Advertiſement.

THere are three kinds of inner *Epicycloids*; the firſt is when the Diameter of the generating circle is leſs than the ſemidiameter of the circle which is in the baſe; the ſecond, when 'tis equal to it; and the third, when 'tis greater; we have ſhewn at the end of the Dimenſion of *Epicycloids*, that is among the interior or inner, that thoſe that are of the firſt and third kind or ſort, are the ſame; for that whoſe diameter of its generating circle is leſs than the ſemidiameter of the circle of the Baſe, is the ſame as that which on the contrary, the Diameter of its generating circle is greater than the ſemidiameter of the circle of the Baſe, if the circle of the baſe is the ſame, and that the generating circle of this laſt, have its diameter equal to the difference which is between the diameter of the Baſe, and the diameter of the generating circle of the firſt; wherefore I ſhall ſpeak only here of thoſe *Epicycloids*, whoſe diameter of the generating circle, is leſs than the ſemidiameter of the circle of the baſe. For that which is of the ſecond kind of inner *Epicycloids*, 'tis a right line equal to the diameter of the circle of the baſe.

Fig. 178. Let the inner *Epicycloid* be M H, whoſe baſe is the circle A B M, and its centre in C, and let the generating circle I H A of the *Epicycloid*, be ſo placed on the baſe, that the point deſcribing H be on the *Epicycloid*. From the centre C of the baſe having drawn the radius C A to the point touching A of the generating circle with the baſe, which paſſes alſo by the centre of the circle. I ſay,

I say, that the right line I H drawn from the extream I of the diameter of the generating circle to the describing point H, will touch the *Epicycloid* in the same point, H.

Lemma 5.

Fig. 179. Let the semicircle be S T A R, whose diameter is S R, and let the circumference be divided into any number of equal parts that you please, so they be even. From the points of Division having drawn the perpendiculars to the diameter S R, and the touchings as T B which are terminated at the nearest perpendiculars which are beneath.

I say, that the sum of the touchants, as T B, without counting the first which is infinite being drawn by the point S, and the last; is greater than the circumference of the semicircle, without counting the first and the last arches of Division.

Lemma 6.

The same things being put as in the precedent *Lemma*, it may be demonstrated, that the divisions of the circle being indefinitely small, the sum of the Touchants cuting as those before, without having regard to the first and last, differ not sensibly from the circumference of the circle, leaving out the first and last arch of Division.

Lemma 7.

The same things being as before, it may be demonstrated that the sum of the parts as A B which are cut off from the perpendiculars of the Diameter of the circle, between the circumference A and that which is cut off B of the upper touchant T B, which is the nearest, may be found less than any small quantity which may be proposed, and by consequence the points as B, may be considered as on the circumference of the circle.

Lemma 8.

Fig. 180. In the circle D H B whose centre is C, and the touchant D A in D, terminating in the Radius C B A lengthned;

Fig. CLXXIV.

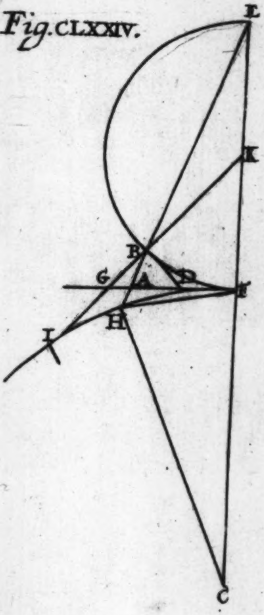


Fig. CLXXV.

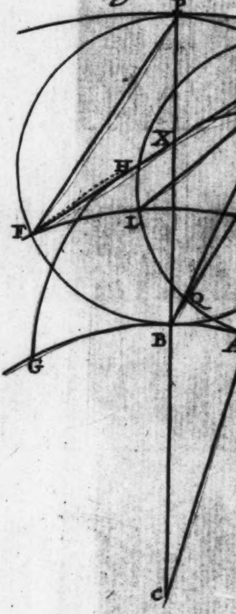


Fig. CLXXVIII.

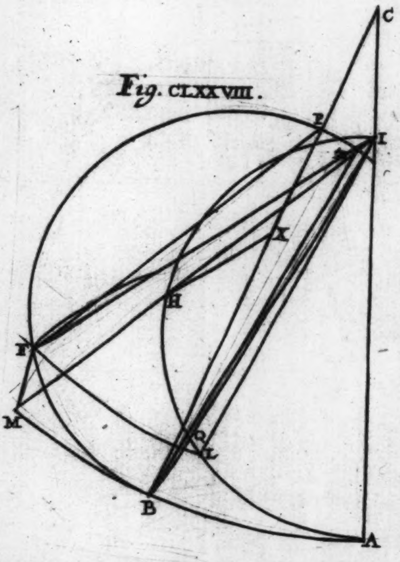


Fig. CLX

CLXXV.

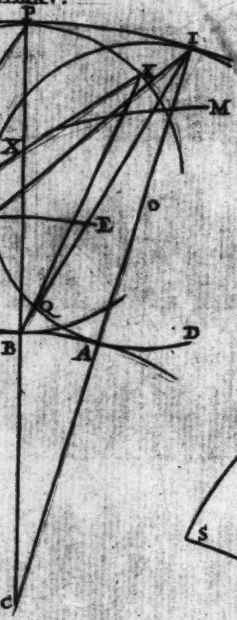


Fig. CLXXVI.

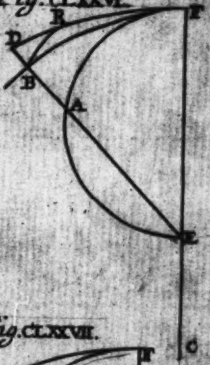


Fig. CLXXVII.

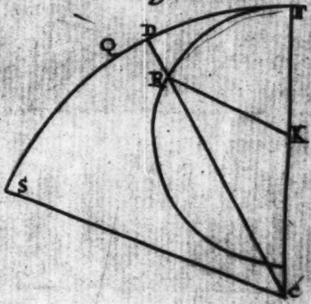
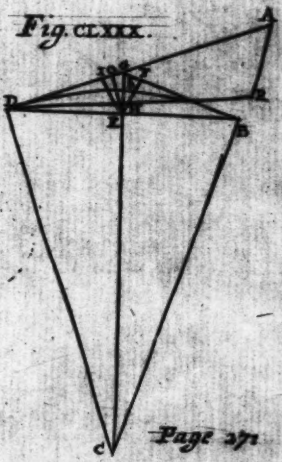


Fig. CLXXIX.

Fig. CLXXX.



ned; having divided the arch D B in two equally in H, and having drawn C H G terminated by the touchant D A.

I ſay, that the double of the touchant D G, or which is the ſame thing, that two touchants together D G, H R, touching in the points D and H, and terminating at the radiuſſes C G, C A, are greater than the arch D H B, but that the difference of theſe ſame touchants from the arch D H B is left leſs than the half of the difference between the touchant D A and the ſame arch D B.

But as in the continual Biſection of arches, we may demonſtrate always the ſame thing, it follows, that we may find a ſum of touchants terminated at the Radij, which paſt through the points touching the next following, which will differ from the circumference of the ſemicircle leſs than any quantity propoſed; and by conſequence theſe touchants may be conſidered as the arches of the circle in a diviſion indefinitely ſmall.

Lemma 9.

The ſame things being as in the precedent, I ſay, that the ſum of the portions of the Radij H G, B R, contain'd between the touchants and the circle is leſs than the moiety or half of the portion B A of the Radius contain'd between the circle and the touchant D A; and for as much as this diminution which is augmented more than half, will be always by the continual biſection of Arches, 'tis evident that we may find a quantity which will be the difference of the Radij between the touchants and the circle, which will be leſs than any ſmall quantity propoſed; whence it follows, that in the diviſion of the circle into indefinite ſmall parts, the meetings of the touchants with the Radij may be conſider'd as if they were on the circumference of the circle.

Lemma 10.

'Tis ſaid in the 6th. *Lemma*, that in the diviſions of a circle indefinitely ſmall, the portions of the circumference differ not ſenſibly from the touchants, being leſſen'd by the method propoſed; and that theſe touchants may be taken for the arches of the circle, we may now demonſtrate the ſame thing in the Epicycloids, and in the Cycloids.

Lamma.

Lemma III.

Fig. 181. The ſemicircle B D A being divided into parts indefinitely ſmall as D F, and by the points of diviſion as F, having drawn the lines M F Z perpendicular to the diameter A B, and by the extream B of the diameter A B, and through all thoſe points of diviſion as D, having drawn the right lines B D M terminating in M in the perpendiculars M F the neareſt to the loweſt.

I ſay, that the ſum of all the portions, as D M of the lines B D M in the ſemicircle, is equal to the double of the diameter A B.

PROPOS. III.

I Say, that the bigneſs of the crooked line of the outer Epicycloid is equal to the right line, which hath the ſame reaſon or proportion to the diameter of the generating circle taken 4 times, as the ſum of the diameters of the two circles, to wit, of the generating, and of that of the baſe, to the diameter of the circle of the baſe.

PROPOS. IV.

THe crooked line of the inner Epicycloid is equal to the right line, which is to 4 times the diameter of its generating circle, as the difference of the diameters of the circles of the baſe and of the Generatour, to the diameter of the circle of the baſe.

PROPOS. V.

Fig. 182. IN the firſt place, I ſay, that when the Diameter of the generating circle is equal to the diameter of the circle of the baſe, the Epicycloid degenerates into a right line ſince, 'tis nothing but the diameter of the circle.

Secondly, If the diameter A B of the generating circle of the inner Epicycloid, is greater than the ſemidiameter C B of the circle of the baſe, but leſs than the whole diameter; I ſay, that the inner Epicycloid is the ſame as that which is deſcribed

bed by the circle D E F, whose diameter D E is the difference between the diameter A B of the generating circle, and the diameter G B of the circle of the base, and the diameter D E will be less in this case than C B, we may find the bigness of this *Epicycloid* by the *4th. Proposition.*

Thirdly, if the generating circle have its diameter greater than that of the circle of the base, the *Epicycloid* which will be described by the generating circle will be an outer *Epicycloid*, which will be the same as the Exterior which will be described on the same base, by another circle whose diameter is equal to the difference of the diameter of the generating circle and of that of the base.

Lemma 12.

What is said at *Lemma* 11. touching the likeness or proportion of D Q to D M towards the parts of the base of the *Epicycloid*, will be the same as for the parts above the point D.

This *Propos.* is evident, since we may make the triangles alike with the parallel lines on both sides the point D, as appears in the Figure.

Lemma 13.

Fig. 183. Let the Semicircle be A M C I, whose circumference divide into parts indefinitely small as C I, I X, from the points of division C I X, having drawn the perpendiculars C B, I E, X R to the diameter A M, and the Chords A C, A I, A X, which meet with the Perpendiculars of the nearest divisions from above to the points F R.

I say, in any Segment of the circle which you please, that all the portions together of the Chords, as C F, I R, contain'd between the circumference of the circle and the upper perpendicular, are equal to the double of the Chord A C; and by the same reason all the portions taken together in the semicircle, are equal to the double of the diameter, which is also the Chord of the Semicircle.

PROPOS. VI.

Fig. 184. IN the *Epicycloid* P D, whose top is P, and any arch P D from its top, the generating circle B D A being put so that the describing point be in D, and that the diameter A K B in this Position tend to the Centre C of the base.

I say, that if we make it, as C A the radius of the base, is to C K composed of the Radius of the base and of the Radius of the generating circle, so the double of the Chord B D of the arch B D of the generating circle which answers to the arch P D of the *Epicycloid*, is to a fourth Proportional, that line will be equal to the arch P D of the *Epicycloid*.

Of the motion or rouling of Epicycloids, *and of the* Cycloid.

Lemma.

Fig. 185. LET the line DTFB be always crooked on the same side about which apply a flexible line; if we open or unfold part of this applied line, so that its part A B betwen its extream A and the curve in B be stretcht out, then by consequence it will be a streight line.

I say, that the right line A B touches the curve or crooked in the point B, from whence it begins to extend it self.

The line described by the end A of the flexible line which is always stretcht out in its opening, is said to be described by the rouling of the curve D T F B.

PROPOS. I.

The Line described by the rouling of an Epicycloid, *is an* Epicycloid.

Fig. 186. LET the *Epicycloid* be B D L, its generating circle F D E, its centre P, and whose circular base is A E L and the centre C, the top of the *Epicycloid* let be the point B.

If from the centre C and the Semidiameter C B we describe the circle B F M, which let be the base of the *Epicycloid* B G K, whose generating circle will be F G H, which has for its diameter F H or B I, which may be determin'd by saying, as C A is

is to C P, so is 2 E F or 2 A B, to a fourth proportional E H or A I; and having taken from A I the diameter A B of the generating circle, there remains B I or F H, which will be the diameter sought.

I say, that the *Epicycloid* B G K is described by the Roling of the *Epicycloid* B D L. By construction, and by the precedent Propositions of the dimension of the lines of *Epicycloids*, it appears that the Curve of the Semi *Epicycloid* B D L is equal to the right line A I or L K.

Now let the flexible line be fitted about the Semi-epicycloid B D L, of which the portion from the point D even to the top B will be extended in the right line D G; this right line D G, by the precedent *Lemma* touches the *Epicycloid* in the point D; Wherefore if we put the generating circle of the *Epicycloid* in the position F D E, or the describing point being in the point D; it is certain by the property of Touchants of *Epicycloids* that the right line D G touchant, passes through the extream F of the diameter E F, in the position F D E of the generating circle.

Having prolonged G E F to H in the circle I H K concentrique in the circle of the Base, which is described on the Semidiameter C I; on F H for a diameter describe the Semicircle F *g* H. I have demonstrated that the extream G of the flexible line stretcht out from the point D, will be on the circle F *g* H.

If the point G is not on the circle F *g* H, and the right line D F G meet, if it may be the circle F *g* H in any point *g*; then draw H *g*; because of the Semicircle F *g* H, the angle F *g* H is right, and the rectangled Triangles E D F, F *g* H will be like, because of the equal angle at the point F. Wherefore E F will be to F H, as F D to F *g*; and being compounded, E F will be to E F more F H, that is E H, as D F to D F more F *g*, that is D *g*; and by doubling the Antecedents 2 E F or 2 A B, they will be to E H or A I, as 2 F D to D *g*.

By *Propos.* the *6th.* of the dimension of *Epicycloids*, and by construction; as 2 A B are to A I, so C A is to C P: But as C A is to C P, so is the double of the Chord D F to the bigness or Magnitude of the portion D B of the *Epicycloid*, which portion by the roling is equal to the right line D G: Wherefore by equal reason 2 A B are to A I, as 2 D F are to D G. But I come to demonstrate that 2 A B are to A I, as 2

 F D

F D are to D g; then 2 D F are to D G, as 2 F D are to D g, and by consequent D G will be equal to D g: then the point g of meeting of the right line D F G, and of the circle F g H, will be the extream G of that line.

It remains now to demonstrate that the point G is in the *Epicycloid* B K, whose generating circle is F G H. By construction C A, is to C P, as 2 A B are to A I, by dividing, C A is to C P less C A that is A P, as 2 A B to A I less 2 A B; but by doubling the Consequents, C A is to 2 A P which is equal to A B, as to 2 A B to 2 A I less 4 A B; and by compounding, C A is to C A more A B that is C B, as 2 A B to 2 A I less 4 A B more 2 A B, that is 2 A I less 2 A B, or only 2 B I, as it appears in the figure.

But in taking the half of the Terms of the last proportion C A is to C B, as A B to B I: But also as C A is to C B, so is the length of the arch A E to the length of the arch B F.

Now by the generation of the *Epicicloid* B D L, the arch of the base A E is equal in length to the arch of the generating circle F D; but because that the two circles F D E F G H touch each other in F, the line D F G cuts the two arches alike F D, F G, whose lengths keep between themselves the same ratio or proportion as those of the Chords F D, F G, or those of the diameters F E, F H: Then the arch F D is to the arch F G, as F E to F H; or as A B to B I, which is also as C A to C B, or as the arch A E to the arch B F: But the arch A E is equal to the arch F D; then the arch B F is equal to the arch F G of the circle F G H, and by consequence the point G is that which describes the *Epicycloid* B G K; which was to be demonstrated.

For the inner *Epicycloids* we may demonstrate the same thing, only changing the form of the proportion: And for the *Cycloid* 'tis easy to behold by the same demonstration, that the line which is described by its roling, is the *Cycloid* equal to that which is roled.

Corollary 1.

Hence it follows also by *Hypothesis* that the 3 lines C A, C B C I are continual proportionals: For C A is to C P as two A B to A I, in dividing and doubling the Consequents, C A will be to 2 C P less 2 C A, as 2 A B to 2 A I less 4 A B: But 2 C P less 2 C A are equal to 2 A P or to A B; and as 2 A B to 2 A I less 4 A B, so A B to A I less 2 A B; wherefore C A is

to

to A B as A B to A I less 2 A B: But in compounding, C A is to C A more A B which is equal to C B, as A B to A B more A I less 2 A B, which is equal to B I; and by Altern proportion C A is to A B, as C B to B I; lastly, being Compounded C A is to C A more A B which is equal to C B, as C B to C B more B I which is equal to C I.

Corollary 2.

'Tis evident as yet that the line which is described by the roling of a circle, is the last of all the outer *Epicycloids*, that is to say, that whose centre of the generating circle is at an infinite distance; or that which is described by the end of a right line which roles about a circle in the Touchant, which doth agree with the roling of the circle.

'Tis easy to demonstrate that the superficies of the figure of this kind of *Epicycloid*, when the describing line runs over the whole circle of the base, or that it comes again to the same thing; The figure described by the roling of the whole circle, without comprehending the circle which makes the roling, is equal to one third of the circle, which hath for Radius the circumference of the circle of which the roling is made. What I say of the whole circle, the same is intended of every part of this Figure. For the figure described by the roling of any arch of a circle, without comprehending any thing of that circle, is equal to $\frac{1}{3}$ of the Sector of a circle, which has for Radius the circumference of that arch, and of which the arch is like to that of which the roling is made; It will be also the same thing for the roling of a greater arch, and of the whole circle. For that which is the crooked line of this *Epicycloid*, or of that which is described by the roling of an whole circle or of any arch, which shall be always equal to half of the circumference of the circle or of the arch of which we take $\frac{1}{3}$ of the superficie, for the superficie of the Figure described by the roling.

PROPOS. I.

Of the use or advantage of Epicycloids *in* Mechanicks.

Fig. 187. LET the right line A D be a determined length, and movable on a Plane about its extream A; and on the same plane let there be another right line C B, indeterminate towards

towards B, and movable on the plane about its extream C: if the Extream D of the line A D is led into E and R, by the line C B, which moves it self on the point C.

I say, that if the lines A D, C B, be placed on the line C A which joins the Centers of movement, and the points D and B be put one upon another, there will be two powers equal between themselves, which will act with all their force on their lines in the points D and B, that is to say, (with direction at right angles) these powers will be in *Equilibrio*; but if the lines change their position, as A D into A E, and C B into C B E, the Powers equal to X being applied always in the same manner to their lines, and to the same places, they will be no more in *Equilibrio*, but to make them in *Equilibrio*, we must have another power Y greater than X applied in B, on C E, and this Power Y ought to be so much greater, as the line C B E is removed from C A.

From the centre C and Semidiameter C D or C B, having described the circle B B, 'tis evident that C E is greater than C B. But from the point E having drawn E G perpendicular to A E, and E F M perpendicular to C E, and by the point A having also drawn H A M parallel to C E, if from any point F of the line E F we draw the line F G parallel to C E, the two triangles F E G, M E A will be alike, for they are rectangled, and their angles in the point E are equally together to a right angle, because of the right angle A E G.

If we suppose now the part E F indifinitely small, 'tis evident that the line C E cannot be moved from E to F about the point C, without causing A E to move to G about the point A. But it follows from the Laws of *Mechanicks*, that to make an *Equilibrio* between the power X applied to the extream or end E of the leaver A E, which moves according as the line E G, and between the power Z applied to the end E of the leaver C E, which moves according to the line E F; it is necessary that X be to Z as E F to E G, that is to say, as A M to A E: In fine, if we suppose the power Y applied to B on the leaver C E in the point B, 'tis evident, that to make an *Equilibrio* between Z and Y, it is necessary that Z be to Y, as C B to C E: It follows therefore, that for to make an *Equilibrio* between X applied to E on the end of the leaver A E, and Y applied in B on the leaver C E, it must be that X must be to Y in the compound proportion, of A M to A E, and of C B

to C E, which is the ſame as that of the rectangle A M, C B, to the rectangle A E, C E. But in the rectangle triangle A M E, the ſide A M will be always leſſer than the Hypotenuſe A E; and by conſtruction C B will be alſo always leſſer than C E, whence it follows, that the power Y will always be greater than the power X, and that the more the lines C E, A E are removed from the line A C which joins the centres of the movement, the more the power Y ought to be greater for to make *Equilibrium* with the power X.

Fig. 187. We may likewiſe demonſtrate the ſame thing after another manner, in keeping to the common principle of the ballance, or leaver. For if on M A lengthned, we take A H equal to A E, and conſider C E and M A H as two horizontal Leavers, the points of whoſe props are in C and in A, and that the end E of the leaver C E have a weight called Z, this weight will have the ſame endeavour on the point E of the elbow leaver H A E, as on the point M of the right leaver or ballance H A M. For 'tis evident, that the weight X in the point H, will be to the weight Z, as A M to A H, or A E its equal. But now if inſtead of the weight Z applied in E on the end of C E, we ſubſtitute a weight Y applied to the point B of the ſame leaver C E, for to make the ſame endeavour as Z in E, it will be, that Y will be to Z, as C E to C B: Then the weight X will be to the weight Y for to make an *Equilibrum* in the compounded proportion of A M to A E, and of C B to C E, as before, whence follows what was propoſed.

Corollary.

It follows from this demonſtration that a power applied in B to the end of the Leaver C B, will not act equally againſt another power applied in D to the end of the line A D in the meeting of its extream D, when theſe lines are differently poſited, their powers will always be applied in the ſame points of their lines C B, A D, and they will act perpendicularly; But then one muſt be ſo much greater as the line C B is more removed from C A.

If you intend the contrary, the power which acts muſt be applied to the end D of the line A D; for this force or power ought to be leſs when the line A D is more removed from A C, than when 'tis nearer.

PROPOS.

PROPOS. II.

Fig. 187, 188. THe ſame things being put as in the precedent, I ſay, that if on the circumference of the circle B B as a baſe, we deſcribe the Epicycloid B H, whoſe generating circle is D E R, and Radius the line A D, the crooked line of this Epicycloid being join'd to the Radius C D of the baſe, and not making with it the ſame mixt line, as in the poſition where it was deſcribed, in any place which C B is placed out of C A; and the end D of the line A D, being put on the Epicycloid in E, the power Z which is applied in E, at the end of A E, as 'tis in the precedent propoſition, will be in Equilibrio with the ſame power Z, which is applied in B to the end B of the line C B, and which acts on the point E by means of the curve of the Eyicycloid B E.

Fig. 188. 'Tis eaſy to ſee in this figure by the forming of the Epicycloid, that in any poſition, which the line C B is in, which is joined to the Epicycloid, the Arches B B will be always equal in length to the arches D E of the circle D E R; wherefore let C B be in any place, and the power applied in B cannot move it ſelf through one arch B B, without moving the other force applied in E on the end of the leaver A E, by an arch E E equal in length to the arch B B; whence it follows, that the powers being equal they will remain in Equilibrio; which was to be demonſtrated.

Fig. 189. We may alſo make this Demonſtration as in the precedent propoſition; and we ſhall find that the ſame method which is managed in the inequality of powers, will lead us here to equality by compounded Reaſon: For if we ſuppoſe that the end E of the leaver A E hath the power X A, which acts according as E G perpendicular to A E, and that in the point E at the end of C E, there be a power V which acts according as E F perpendicular to C E; 'tis evident by the nature of the Epicycloid, that the line N E drawn by the end N of the diameter D A N to the point E, will touch the Epicycloid in that point; and that as when the point E of the end of the leaver C E ſhall have run over a ſpace E F indefinitely ſmall, the ſame point E of the end of the leaver A E will be come to G, where the line F G, parallel to E N, meets E G perpendicular to A E; for the ſmall portion F G of the Touch-

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Fig. CLXXXI.

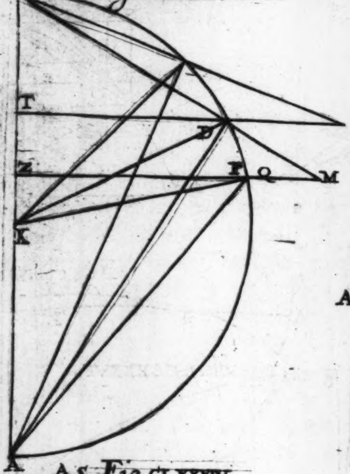


Fig. CL

Fig. CLXXXIV.

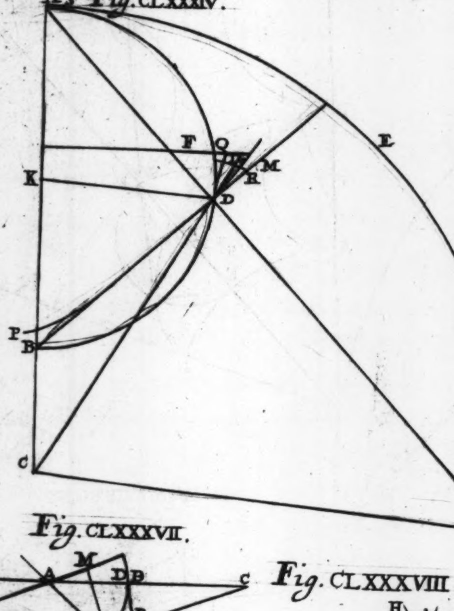


Fig. CLXXXVII.

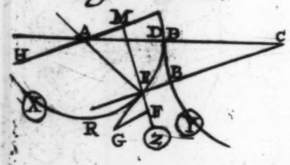


Fig. CLXXXVIII

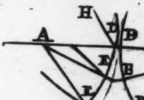


Fig. CLXXXII.

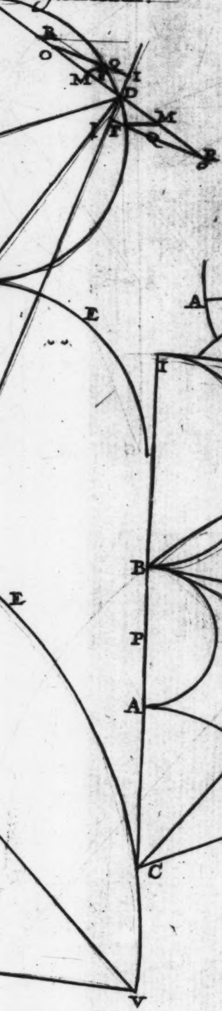


Fig. CLXXXIII.

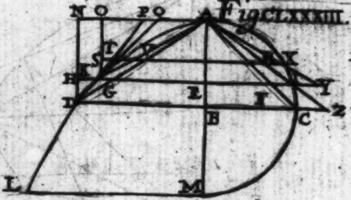


Fig. CLXXXV.

Fig. CLXXXVI.

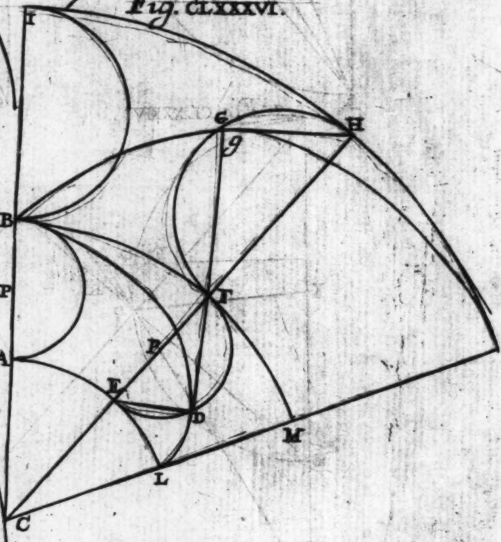
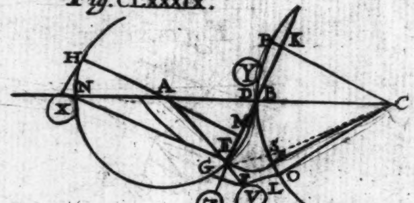
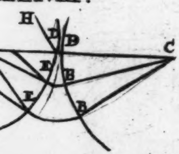


Fig. CLXXXIX.



XXXVIII.



ant E N may be considered as the same curve. But having drawn F C which meets the circle B B in L, the arch S L of the circle B B between C E and C F, will be equal in length to E G by the nature of the Epicycloid; for when the point E of the Epicycloid shall be come to G, the beginning of the Epicycloid B on the circumference of the circle B B will become to O; so that the arch B O will be equal to S L.

The Power X runs over then the space E G, when the power V runs over E F, and for to make an Equilibrium between these two powers, it must be, that Z must be to V, as E F to E G, that is to say, in reciprocal reason of the spaces run over. But lastly, if we suppose the power Y in the point S, or in the point B, on the circumference of the circle B B, and that it makes Equilibrium with the power V, it will come to pass that V will be to Y, as C B to C E; then the power X will be to the power Y, in the compound reason of E F to E G, which is the same as E F to S L, or that of C E to C S or C B, and of C B to C E. But this compounded reason is a reason of Equality, wherefore the powers X and Y ought to be equal for to make Equilibrium between themselves, being applied, as we suppose, which was to be demonstated.

Corollary.

That which I come to demonstrate of the Epicycloid described on the circle B B, for its base and for its generating circle D E, whose Radius is A D, the meaning is the same, if the Epicycloid be described on the circle D E for the base, and that the generating circle be the circle B B, and its Radius C B; for the movement or motion will be always equal from one side or tother.

PROPOS. III.

How to make the Application of motion equal to Engins.

Fig. 190. Let there be a circle B O L whose centre is C, and another circle D E F whose centre is A: On the circle B O L, as a base, and for a genenerating circle D E F, describe the Epicycloid B V H, and divide the circumference of the circle B O L into any number of parts, as here

into eight in the points B K L, *&c.* and to each of these points apply a portion of the Epicycloid B V H, in K I, L M, which will be the same as if the Epicycloid had been described, beginning in the points K L, *&c.*

We may likewise take as great a portion of the Epicycloid as we please, as B V H, and by this means make the divisions of the circle lesser or fewer. The figure B V H G may be the tooth of a wheel which may be limitted by the right line H G, which tends to the centre C of the circle, or by any other line as you please, which is indifferent, since this part of the tooth doth not cause any effect. We may also hew a little the space between two teeth, as D N O, to give the more liberty to the meeting of the parts of the other wheel D E F.

We may then form a wheel on the model of a circle with its teeth, and make it move on the centre C.

Now if we apply another wheel to the hinder part of it, whose centre is in the point A in the Horizontal line A C, and that instead of teeth, on the circumference D E F, we apply only in this example the pegs or pins of wood D E F, *&c.* which we suppose indefinitely small and perpendicular to the plane of the wheel; 'Tis certain by the precedent proposition, that in any position that we place the wheel B O L whose teeth meet the pins of the other wheel D E F, they will be in Equilibrio, if the moving forces applied to the Circumferences of the two wheels be equal between themselves.

Let then for this effect a weight Q be hung from the circumference of the wheel B O L, equal to the weight R, hung and applied to the circumference of the wheel D E; these two weights will then abide always in Equilibrio in any manner that the teeth of the wheel B O L meet the pins of the wheel D E F.

But if we apply a weight P to the circumference of another wheel S T, which hath its centre common with that of the wheel B O L, and which is fastned with it, this weight P will be to the weight Q, as C B to C S, the weight P will be still in Equilibrio with the weight R, in all the different meetings of the two wheels; for the weight P making Equilibrium with the weight Q, it will also be in Equilibrio with the weight R.

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PROPOS. IV.

THings being disposed as in the precedent, I say, it matters not whether the divisions of the wheel B K L be equal between themselves, that is to say, that the teeth be equally distant one to another, nor the pegs D E F on the circumference of their wheel.

It matters not whether it have one or more teeth of the wheel B K L, which act all together on the pins of the wheel D E F, for there will be no more but the same force which will be applied against that of the wheel D E F. If it have but one, as B V H, all the force of the weight P, will act against that of the weight R, in meeting with the peg D.

Fig. 190. If you would have two together, as B V H and K I, of which the first acts on the peg D, and the other on the peg E, 'tis evident by the construction of these teeth, that K I will have as much force or power on the peg E against the weight R, as B V H on the peg D against the same weight R; and by consequence the force of the weight P distributes it self equally to these two teeth, each of which counter-ballances the moiety of the weight R: It will be the same thing, if you have three or more which act all together.

Thus it matters not if you have one or more teeth which work all together, and 'tis indifferent what part of the tooth meets the peg against which it acts, since it will have always the same force; which was to be demonstrated.

PROPOS. V.

THe Engin being disposed, as before, for to make an *Equilibrium*, between the two weights P and R; I say, that if you augment the moving force of the wheel B K L; or, which is the same thing, if you add some weight Z to the weight P, this force, or this new weight will act equally in all the different encountrings or meetings of the toothed wheel E K L with D E F, on the force, or on the power; or lastly, on the weight R applied to the wheel D E F.

Since to make an *Equilibrium* between the weight P, augmented by the weight Z, and the weight R, you must augment the weight R with the weight Y, which must be to

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the weight Z (which makes the augmentation of the weight P) as C S to C B, and then the two weights R and Y together will make through all an *Equilbrium* with the two weights P and Z together; 'tis evident, that in any position which these two wheels are in, the weight Z will be always in *Equilibrio* against the weight Y; and by consequence the two weights P and Z together prevail always with the same force against the one weight R, which is measured by the weight Y, since it wants this weight to make the *Equilibrium*, which was to be demonstrated.

PROPOS. 6.

WE may place the Superficie of two Wheels in the same Plane, and instead of the pegs or pins which should be fastned on the Wheel D E F, we may make the teeth at the end of this Wheel, and give them what Figure we please: But then the teeth of the other Wheel whose figure will be in the *Epicycloid*, ought to have a figure composed of those of the *Epicycloid* and those of the teeth proposed, this compounded figure forms it self, as I shall explain in the following Examples.

Example 1.

Fig. 191. The most simple of all Figures is the Circular; wherefore I propose at first sight the figure of the teeth of the Wheel B E F in a circle. Let the wheel be B E F, whose centre is in A, which hath its teeth of a circular Figure, as B O P, and whose centres will be on the circle D G M, which hath its centre common with those of the Wheel A; let the centre of the other Wheel be C; having drawn the right line C A which joins the centers of the two Wheels, and which meets with the circle B E F in B, from the centre C, and with the Radius C D describe the circle D I, on which as a base make the *Epicycloid* D V H, which hath D G M for its generaing circle. Now if from all the points D V H, of the *Epicycloid*, as Centers you describe the circles O N L equal to the circle which forms the teeth of the Wheel B E F, the crooked line O N L which touches all the circles, and which will be Parallel to the *Epicycloid*, will form the figure of the teeth of the Wheel B K, that is to say, that part of the tooth which acts against the part of the circular tooth which it meets in its motion, for to the other parts of the teeth which it meets not with, I have already said that they may be made

made of what Figure you please; but you ought always to make choice of those which are most durable, and most proper to resist the force of the motion.

I say now, if you apply equal powers to these Wheels within the distances of their centers C D, A D, in any place that the teeth meet, you will have an *Equilibrium* every where; only it must be observed that the meetings of these Teeth must be always under the line A C.

By the 3*d.* Proposition in any place that the *Epicycloid* D V H is applied to the point D of the Wheel D G M, in making it move about the Centre A, it will make an *Equilibrium* between the equal Powers. For if one of the powers cause the other to move, it will cause it to run over a space equal to that which the same runs over it self. But by construction of the tooth O N L, we see that the crooked line O N L meeting the circle B z P makes the point D so much advance, as if the *Epicycloid* D V H met it: For the distance between the *Epicycloid* D V H, and the crooked line O N L is every where, that of the Semidiameter of the Circular tooth B z P.

For example, when the centre of the tooth D is come to G, and that the *Epicycloid* D V H is placed in I G, its point G being joyn'd to the centre of the circular tooth, 'tis evident that the arch D I of the circle of the base will be equal in length to the arch D G of the generating circle D G M; But then the crooked line O N L will be placed in *o n l*, and the circular tooth E *n p* which hath its centre in G, will necessarily touch in the point *n*, the crooked line or curve *o n l*, for the shortest distance, from the point G of the *Epicycloid* to the curve *o n l* will be in the point touchant *n* of the circle E *n p*, and of the curve. So when the point D of the *Epicycloid* is come to I, the point O of the curve will be come to *o*, the arch O *o* will be equal to the arch D I, and the curve *o n l* which meets the circular tooth in *n*, will be made to advance its centre in G on the *Epicycloid* I D, and by consequence the arch D G will be equal in length to the arch O *o*, or D I.

I have said that the teeth ought not to begin to meet or rencounter themselves but underneath the line A C, that is to say, that the bending O N L is not proper for to act on the circular teeth, but when the point O of the curve O N L is come to D; and by consequence this curve O N L begins not to act against the curve or bending of the circular tooth, but in the point

point Z, where it is cut by the circle D G M, and it continues always in the Rencounter or meeting in its part Z P, in descending beneath the line A C. We may then lessen all the part Z B of the circular tooth, since 'tis not useful in the movement, or motion, and finish it on the circle Z D. We may also finish the teeth of the other Wheel by the curve L N O, and by the circle O D, which will be the ground of the teeth; But in this construction we ought to distribute the teeth after such manner in each Wheel that they begin to rencounter or meet one another only in the line A C, and that they do not hinder one another above, which will always be easy to do.

Also note, that the curve L N O Parallel to the *Epicycloid*, begins always out of the circle O D I, and afterwards that it is between, or within; and lastly, that the diameter of the generating circle is greater than D B, which is easy to demonstrate by the generation of the *Epicycloid*; but I consider not in this place but the part O N L of this curve which is without the circle O D I when 'tis in this kind.

We ought always to avoid in the teeth of Wheels to make them work above the line A C which joins their centers, because the wearing or rubing in them is very great, and that on the contrary 'tis not almost considerable in them below, supposing that the motion of the Wheels will be from above to beneath the line A C. In the mean time if you would that the teeth of these Wheels work in rencountring themselves above A C, it must be in the making, as I shall shew by and by, after I have shewn a general method for making the teeth of one Wheel in different manners, those of the other being always given the same.

Example 2.

Fig. 192. Instead of the Centre D of the circular tooth proposed, as in the precedent example, I take another point like that where I please, as B on this tooth, and by means of this point I find the figure of the tooth B N N, which ought to work with the proposed; but for to cause the tooth proposed to act or work in as many parts as is possible, we ought to chuse a point in this tooth which may be the nearest to the Centre C of the other Wheel, in the motion of this point chosen

chosen about the center A of the Wheel unto which 'tis fastned; and this point will be the point B in this Example.

From the centre C and with the Radius C B describe the circle B K, which will be the base of the *Epicycloid* B V V, whose generating circle is B G G described from the centre C and Radius A B; then from the centre A having drawn the Radius A G, from the centre C, and by the Radius C G we may describe the circles G V, which cut the *Epicycloid* in V, and by these points V we may draw the lines V H I, which make the angles C V I equal to the angles C G A. Then on the lines V H I we may apply the figure B z of the tooth proposed in the same manner as 'tis applied to the line A B, in making it agreeable in the point B or V, and we may draw the curve line B N N that shall touch the curvature or bending of the proposed tooth, in all these different Positions, which same thing will happen for the circle, if we take on V H the Magnitudes V H equal to B D the radius of the circle of the proposed tooth, and that from the points H for a center we describe the circles N equal to those of the tooth.

It plainly appears by this formation of the curve B N N that in any position that it meets the circular tooth, the point B of the curve B N N being beneath A C, there will be every where an *Equilibrium* between 2 equal Powers applied to these Wheels in the distances C B, A B, from their centers C A: For we may demonstrate, as in the preceeding example, that in any position that the curve B N N is applied to the circular tooth, it will be disposed to make its way in the point B on the circle B G, a space equal to that which the same point B makes on the circle B K. For example, if the point B in runing over the space B K on the circle B K, the same point B comes to G, by means of the *Epicycloid* B V, which must be placed in K *u*, but the curve B N N will be placed in K *n*, and its point N will be applied in the point *n*, of the circular tooth B Z, transported in G *n*, which will have its center in *h* on A G, and by consequence the curve K *n*, which acts on the circular tooth G *n* in the point *n*, makes the point G to advance, so much, as if the *Epicycloid* should be placed in K G, and joined to the curve K *n*.

'Tis easily seen, that if the tooth of the Wheel B K is formed as the curve B N N, it will begin to act on the circular tooth B Z, in the point B on the line A C: For so soon as the point

B of

B of the curve B N N is come to A C, and that it touches the point B of the circular tooth, the 2 teeth begin to act one against the other, and to measure how much the tooth B NN descends its different points N, as they are applied in different places of the circular tooth B Z.

Note, that if we take the lines V H I equal to B A, all the points I will be in the circumference of the circle A I I, whose center is in C; and moreover, that all these points I will be the Centers of the generating circle of the *Epicycloid*, in the different positions whence it describes the points V.

Lastly, we may take the point B for the Commencement of the *Epicycloid* in what place you please, whether within or without the tooth, instead of taking it in B on the curve of the proposed tooth, as is done in this example, and we may find always a curve for the tooth which ought to work with those proposed, and which ought to make an *Equilibrium* between two equal Powers, which I shall explain in the following Examples.

Example. 3.

Let the right lined tooth be Z D, which makes with the Radius A Z the angle A Z D, and let the point be D of this tooth which ought to begin to work with the tooth of the other Wheel B K; having taken any point B in the line A D C which joins the centers, and which passes through the point D, determining to what place the tooth A Z D should be made to move on its center A; or if the point D be not determin'd on the tooth Z D, and that there be given the point B of like position to the line Z D, or to the angle A Z D, having drawn A B which cuts Z D in D, we may place the line A B on the line A C, and describe the circle B K from the center C, and the Radius C B; this circle will be the base of the *Epicycloid* B H M, of which the generating circle is B G, described from the center A on the Radius A B.

Then to all the points G of the circle B G, having drawn the Radius's A G, and from the Center C, and for the Radij C G having described the arches of the circle G V, which rencounter in V the Epicycloid B V M, I draw C V, and afterward V H I, which makes the angle C V I equal to the angle C G A; on V I, I apply the line H Z in the same manner that

D Z

D Z is applied to B D A, that is to ſay, that V H is taken equal to B D, and that the angle V H Z, is equal to the angle B D Z, the lines H Z will interſect them all, whence we may draw the curve line D N which will touch them, this line D N will be the figure of the tooth which we ſeek, and which ought to be applied to the wheel B K.

'Tis evident by what is demonſtrated before of the formation of the ſecond teeth on the firſt which are given, that the curve D N of the tooth applied to the wheel B K meeting the right lined tooth D Z below the line A C, and beginning in the point D will make every way an Equilibrium between 2 equal powers applied to the 2 wheels in the diſtances of C B and A B, that is to ſay, in the extream of their Radij; for if we ſuppoſe that the line C B have tranſported the point B to K, the Epicycloid B V M will be placed in K G, and the line A B will be placed in A G, ſo that the arch B G will be equal in length to the arch B K by the property of the Epicycloid. But then in this poſition, the tooth will be in A S *d*, and the curve D N being put in E *n*, its point *n* which is the ſame as the point N, will touch the tooth in *n*; and even as in all the points as G and K the motion will be equal, there will be every way an Equilibrium between the two equal powers.

Where Note, That we ought not to determine the length of the right lined face Z D of the tooth towards D; for it may happen in ſome caſes that the curve D N may not be touchant to all the lines, as H Z, for theſe lines H Z interſect not, their extream H being determined and they rencounter not the next; and if we ſhould draw the curve line D N N through all the points as H, it would happen that only the end or extream D of the tooth would work, and would notwithſtanding make the motion equal, but this is not that which is propoſed in this place.

Example 4.

Fig. 194. We may yet make another ſort of right lined tooth, the face of which tends to the center of its wheel, and by this means the tooth which acts againſt it, has not its face inclined to the circle on which it is faſtned, as in the preceeding

Examples, and this kind of tooth is one of the easiest to execute in great Engins, and most useful for the motion.

Let the face be F D of this right lined tooth which tends to the center A of its wheel, and which is placed in the line A B C which joins the centers of the wheels. By any point B of the line A C, and from the center C, describe the circle B K which is the base of the Epicycloid B V, whose generating circle is B G, described from the center A and the Radius A B; having drawn all the Radij A G, and the lines C G which are the Radij of the circles G V which rencounter the Epicycloid in V, whence the angle C V I will be made equal to the angle C G A. Lastly, whence we may draw the curve D N N which will touch all the lines V I in their different positions, and which will be the figure of the tooth which ought to be applied to the wheel B K. This tooth D N N rencounters the face F D in all its different positions, and will make every way an Equilibrium between 2 equal powers applied to their wheels in the distances of C B and A B. For the curve D N N being placed in *d n*, which is fastned to the Radius C K and rencounters the face A F D of the tooth proposed in *n* in the position A G, will make the same effect on the point G, as the Epicycloid D V placed in K G, as I have made appear in the preceeding example.

'Tis easy to behold by what is explained before, that it will not be difficult to form the tooth which we seek, that which is given being of another figure than the circular or right lined, as Parabolique, Hyperbolic, and the same in the Epicycloid.

PROPOS. VII.

ONe may describe an Epicycloid on a base which is concentrick to the wheel which carries the proposed tooth, and by means of this Epicycloid, we may find the Figure of the second tooth, as in the preceeding proposition.

Fig. 195. Let Z D be the figure of the tooth proposed which is applied to the wheel Z, the center whereof is A; and on this first tooth mark the point D, which ought to begin to work or act with the second tooth that we ought to apply to the other wheel, place the tooth Z D in making it turn with

with its wheel about the center A, ſo that its point D be on the line A C, which joins the centers of the 2 wheels; in this poſition of the tooth Z D, having markt any point B that you pleaſe on the line A C, from the center A, and with the Radius A B deſcribe the circle B G, which will be the baſe of the Epicycloid B V, whoſe generating circle is B K, deſcribed from the center C and Radius C B.

'Tis evident by what is demonſtrated before, that the Epicycloid B V being faſtned to the Radius A B, will ſo much advance the point B from the Radius C B, as the ſame point B advances on the circle B G in any poſition that the Epicycloid ſhall be, as if it is tranſported to G K, the arch B K will be equal in length to the arch B G, and ſo the difference being every way the ſame of theſe arches, they will alſo be equal in length, in manner as if the Epicycloid is placed in G K, the point G will not advance any ſpace, but will be on its arch B G, and it makes not ſo much to advance the point K on the arch B K.

Now to all thoſe points K of the circle B K, having drawn the Radij C K, and afterwards A K, and from the center A and Radius A K, having deſcribed the arch K V which cuts the Epicycloid in V, and the line A C in F, whence the arch K L will be equal to the arch V F, and then drawing L A which will cut the arch B G in G, whence 'tis evident, that the portion B V of the Epicycloid may be accommodated in G K.

Having made the angle C B I equal to the angle C K A, and B I being equal to K A, whence alſo the angle B I *g* will be equal to the angle K A G, and on *g* I equal to A B, or to A G, if we apply the curve E N Z of the tooth given D Z, in the ſame manner that it is applied on B A, as if we tranſport it ſo that the point B be put or placed in *g*, and the point D in E.

Laſtly, the Curve of the propoſed tooth in all its different poſitions will form another curve N N D by a line which will touch them all, which will be the figure of the ſecond tooth which we ſeek, and which ought to be applied to the wheel B K, or to the radius C B D in the manner which 'tis deſcribed.

'Tis evident, that this curve N N D will ſo much advance the point B on its arch B G, as the ſame point B advances on B K: For when the point B is placed in K, the curve N D will advance the tooth Z D in S *n d*, for the point *n* of this

curve which rencounters the tooth in the position S *n d*, rencounters it in the same manner, and in the same place as the point N which it forms. So the *Epicycloid* will be in the position G K, and by consequence two equal powers being applied to these two wheels in the distances of their Radii A B, C B, will act every way equally, and will make an *Equilibrium* in all the Rencounters of the teeth of the two wheels.

PROPOS. VIII.

To apply a little Wheel instead of a Tooth to the Wheel of an Engin.

Fig. 196. I Have noted in the 6th. Proposition, That the second Tooth ought not to begin to work with the first, but on the line A C; because that the wheels having their motion above or below this line, the faces of the Teeth which rencounter themselves in their removing one from another, do only rub one another in making their escape, which causes not any sensible hinderance to the motion; whereas when the rubing is made by the rencountring of the parts which venter or come upon one another, the Impediment to the motion is very considerable, and is that which we chiefly ought to avoid in Machines and Engines.

Behold here a particular construction for the Teeth of Wheels of a great Engin, where the faces which rencounter themselves or meet, are made so that they touch one another without rubing or wearing, and what remains is only made on the Axis, or Pivot.

The construction of these Teeth is the same as those of the first Example of the 6th. Proposition, but the Application is different: In the 6th. Proposition the circular Tooth proposed is stayed firmly by the Wheel; but in those here that is a little wheel which is movable about its centre D, on an axletree, or pin, placed at the end of the Radius A D; there will be then no other fretting, or wearing, in this Engin, than that of the little wheel B Z P on its axis; for the circumference will apply it self every way, without fretting, or wearing, on the Curve of the other Tooth Q N L.

'Tis

Fig. CXC.

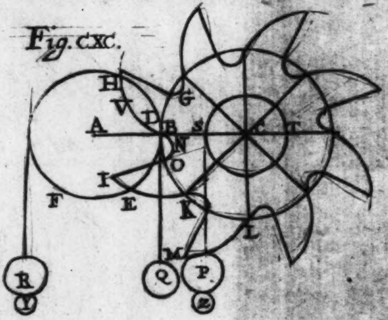


Fig. CXCI.

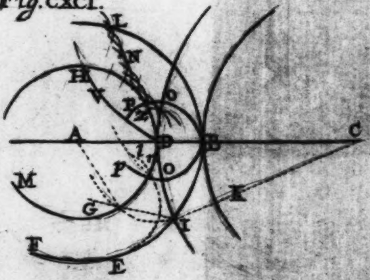


Fig. CXCIII.

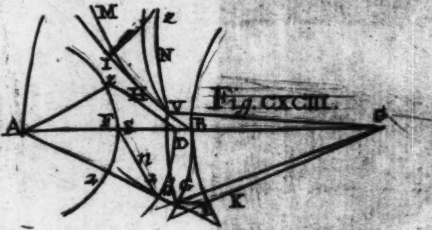
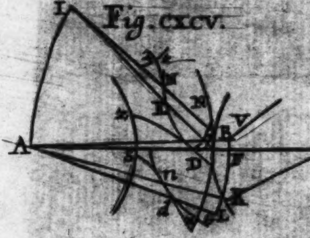


Fig. CXCV.



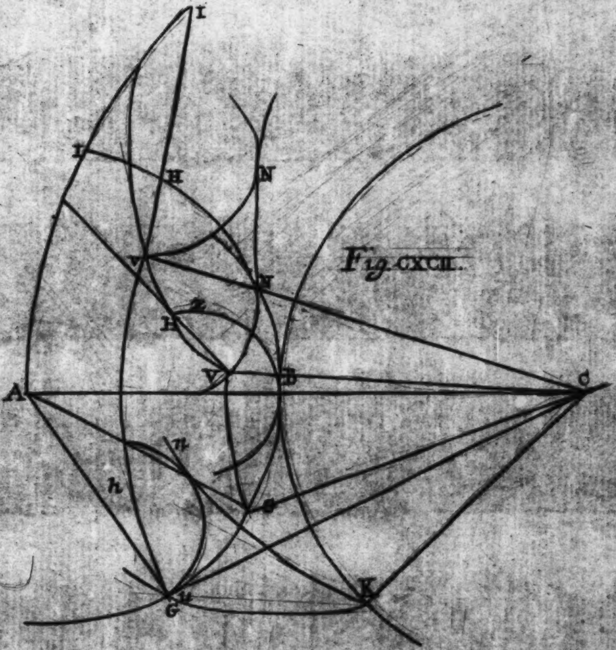
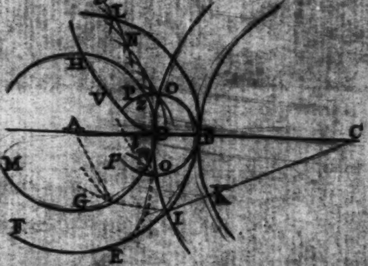


Fig. CXCIII.

Fig. CXCIV.

Fig. CXCVI.



'Tis evident, that this application of the little wheel cannot make any varying from what I have demonstrated of the circular Tooth in the 6th. Proposition, and that the effect of the Engin will be the same: For it matters not whether the Curve O N L rencounter or meet the circle O Z P of the little wheel, or the tooth of the same figure, since its center D will be always the same way.

PROPOS. IX.

The Construction of an Engin to raise Water according to the precedent Form.

Fig. 197. L M O I is a great Wheel made of great pieces of wood joined together one with another, which is posited or placed horizontally, the Axis, or Tree A B, of this Wheel is a large piece of wood which is moved by its base on a Pivot, or Spindle P, being only fastned at top with a pin of Iron to keep it always perpendicular: This Wheel is toothed, or waved, on the edge after the manner of Wheels in rencountring, or meeting, in common Clocks; and it hath but 5 Teeth, as O I, which act in passing upon the little Wheel R S, which is movable on its axis C: This Axis is fastned to the arm D C, which is likewise movable about its axis D, which is stayed firm at any union: The arm D C is join'd and fastned to the portion of the circle D E F, so that they cannot move the one without the other; on the thickness of the arch E F it must have a double flat chain H G, fastned towards the top in E, and this Chain hath two rings at the end of it, which sustains the handle of Iron which carries the Pin, or Pestle, of a drawing Pump: The Leaver, or Arm N, of this Engin passes in the Tree in B, and may be stayed if one will by the wheel to make it more firm; it must have two little Wheels, such as those I am coming to describe, which are diametrically opposite under the Wheel, and which do always act by turns one after another; for by this disposition of the little wheels when one appears in the bottom, or hollow of the wave, the other appears on the top: But the Wheel turning from O to I, the little wheel descends in the rencounter to the part O Q of the wave, and amounts again in the other, we must consider

consider but the part O Q of the wave, for there is but that that works for to lower the little Wheel which raises the Pestle, or Sucker, of the drawing Pump, and which sustains all the weight of water; the little Wheel mounting again in the other part of the wave makes not any effort or endeavour against the Wheel, for it follows only the hollow turning, or winding of the Tooth, not being raised but by the weight of the Pestle, or Sucker, and its handle, and of the Triangle D E F, which fall again beneath by their proper weight, which we may make very near equal to that of the little wheel.

All the effort of the Wheel is made only by its weight in such manner, that if it is as heavy as the weight of the Column of water which it ought to sustain in the body of the Pump, the distance of the Leavers being compensated, 'tis evident that there will not be any considerable rubing on the pivot P: but it must be always somewhat heavier, so that it may not go out of the Iron wherein the Pivot plays, for otherwise it will work on the two little wheels all the time, which must be avoided.

The number of Teeth of this Wheel ought to be odd, so that it may have always one of the two little Wheels opposite which work, and that the power which moves the leaver N, may act always equally, and not by jumps or skips, as it commonly happens in those Engins which have not one or two wheels. 'Tis in this that the principle direction of the construction of Teeth, and the position of small wheels consists: For which, that we may always keep to the rule in the form of the Teeth, we must have respect to the proportions of the height and length of the Teeth with the diameter of the wheel.

We must observe that 'tis not possible that the face of the Teeth, or of the waves of the wheel, should work in every place on the little wheel at equal distances from the Axis of the wheel, because the motion of the wheel is circular and horizontal, and that of the little wheel is vertical or perpendicular; for it happens that when the Teeth rencounter the little wheel in their lower part, and from their point, if the Axletree of the little wheel is equally removed from the Axis of the wheel, it will be nearer when the little wheel is towards the moiety of its descent, which will be easily known in the plane; this difference of removing will cause a little fretting or

wearing

wearing of the face of the Tooth with the little wheel: But these are such faults which are impossible to be wholly avoided in Engins, and we ought to respect those which have the least, or the least considerable, for the most perfect.

For the construction of the Teeth of the great wheel of this Engin, we ought to consider them as if they were in the same plane as those of the little wheel, and when we have determin'd the figure, we apply it on the wheel to the place where it rencounters, or meets the little wheel, serving as a profile or fit size cut from the figure of the Tooth.

Fig. 198. Having determined the center D of motion of the arm D C of the little wheel R S, and the size D C of the arm, from the center D, and by the Radius D C describe the circle C E, on which draw the line A B C touching in C; on the line B A for a base, and C E for the generating circle describe the Cycloid C V V, and through all its points V V as centers describe the circles N equal to those of the little wheel; I say, that the crooked or curve line S N N which touches all those circles will be the figure of the Wave.

If we imagin that the right line B A moves from B towards A on the same with the Cycloid C V V which is fastned to it, 'tis evident that every point B of the line B A will have so much of the way as the point C will have about the center D, being moved by the Cycloid V V: For if the point C of the line B A is transported in T through the space C T, the Cycloid C V will be placed in T E, and the point C will be arrived at E, on the arch of the circle C E: But by the generation of the Cycloid, the arch C E is equal in length to the right line C T, then two equal powers one of which moves the line C T on the same, and the other moves the point C about the center D, will make an Equilibrium every where, for we ought to consider the right line B A as the circumference of a circle whose center is infinite or endless.

But now if instead of the point C of the Radius D C, we apply the little circular wheel R S, whose center is in C, 'tis plain by the construction of the curve S N N that it will have the same effect on the center C of the little wheel in rencountring its circumference, as if the Cycloid C V V should rencounter only the point C: For the center C being put or placed in E, the point N of the curve S N N will be placed in *n*, so that E *n* will be a shorter distance from the point E of the curve.

In

In the construction of the Teeth of this Engin, one serves not all the curve S N N form'd on the whole Cycloid, but only on one part, and that which you please, for otherwise it would happen that the waves would be too great. We may then take for Example in *Fig.* 31. the middle part N X of the whole curve S N X F, which is formed on the half Cycloid C N; so the bottom of the wave will be formed by the circle of the little wheel in the position N Z P, and its point will be in the point X; we may give very near the same figure to the part of the Wave which mounts up again and works not, to the intent that the little Wheel may roul away more easily in remounting within the bottom.

Fig. 199. We must note, that when the little Wheel is come to the end X of the Wave, the center M of the little Wheel is not so far as it may be from the point X, that is to say, that the line M X is not perpendicular to B C: But as the point X describes a line parallel to B C, it works only on the circumference of the little Wheel, until that the point M is come within the line M X, perpendicular to B C; the center M of the little Wheel will describe then in that place a small arch of a circle equal to those of the little Wheel, and it will happen that the point X of the wave will be blunted or dulled a little in the succession of the work, which will not happen if one serves for all the curve N X F; for the wave will not be one point from its extream F, as in the point X, because that the Touchant of the curve in F is Parallel to B C, and the Touchant in X is inclined to the same line B C: 'Tis evident, that the work of the point X will only endure so much more time as the little Wheel is more great; for the arch which the point M describes, will be greater for drawing the point M, in the line drawn by X perpendicular to B C, than if the Radius of the little Wheel should be lesser: There is still one inconveniency in a great little Wheel; for it must have greater ballances on one side, and on the other under the wave, because that it moves on two points one of which is its Pivot, and the other is that of the arm and of the Portion of the circle which carries the chain, which will not be so considerable in a small Wheel: But if the little Wheel be very small, it must take away a greater portion of the curve N N, to form the wave that it may have always the same Elevation in the pestle, or rod of the Pump.

'Tis

'Tis easily seen that the chain which is fastned to the portion of the circle serves to raise the Pestle always perpendicular, which is a very good use in these sorts of Pomps: For otherwise if the handle which carries the Pestle, be only fastned to a Leaver movable about an axis as D in this Engin, it will happen that the Pestle will be drawn sometimes to one side, and sometimes to the other, and wear unequally in the body of the Pomp in working, which will destroy it in a third part of the time, as I have observed in some rencounters.

PROPOS. X.

We may likewise apply the same construction to wings, or to the Axle-tree of Mills, which have their Wheel vertical, and which are for Powder, for Paper, for Fulling, for Forging, &c. *or it may raise Pestles, very near as you see represented in this figure.*

Fig. 200. I Shall here represent only two of these Pestles, but we may put as many as we please, or as many as the mover of the Wheel can make to go; you must always put two wings opposite, as A B and C D, to work on each Pestle, to the end that when one of these Wings as B having quitted the little Wheel E from the arm of the Pestle, and that it is fallen, then immediately the other Wing A, which is opposite to B, begins to relieve it.

We may also observe that if we have two Pestles, it behoves that the wings which belong to each one, will be applied one after another, to the axis of the Wheel, as we see here, where the Azis is to 4 Panes, because that it hath four wings and two Pestles, and where the wings A and B are applied to the two opposite faces of the axis, and the two other wings C and D, which belong to the other Pestle are applied to the two other opposite faces of the same Axis: If we would then have three Pestles and six wings, we must cut the Axis, or Tree, into 6 panes, or sides, and if we would have four, we must cut it into 8 sides, unless we apply two Pestles on the same face, and then there needs but half of the faces to the tree.

But it must be observed that we do not place the wings together, which are applied to the same face, but to mingle them with the others, that so the Endeavour, or effect, may distribute it self equally on the Axis, or tree, that is to say, that the raised Pestles should not be together.

I do not represent in this figure but one of the kinds of making the motion equal, which is by giving a crooked figure to the wings which are fastned to the Axis of the Wheel, and by placing the little Wheels to the end of the arm of the Pestles, although there be yet another, in making the arms of the Pestles of a curved or crooked figure, and in applying the little Wheels to the end of the right wings of the Axis of the Wheel: But I will explain these two kinds in the construction of the Curves or Crooks.

I have not given here the conjunction of this Engin, nor the manner of strengthning all the pieces, 'tis sufficient for him that regards the Mechanicks to shew the disposition, the rest belongs to the Art of Carpentry.

The first kind. Fig. 201.

The first kind of applying the Curve to this Engin is that which is represented in the precedent Figure; let the point C be the Center of the Axis of the great Wheel, and C A the distance from the Center to the handle of the Pestles, on the right line C A having determind the point B, which is the extream A B, of the arm of the Pestle, and which is the Center of the little wheel which we apply to the end or extream of the arm; and from the center C, and by the Radius C B, having described the circle B D, make the *Epicycloid* B V V on the circle B D for the Base, the generating circle having its center at an infinite distance, that is to say, that the circumference of this circle is a right line, and that the *Epicycloid* B V V is the last of all, which is also the Curve line described by the roling of the circle, as is noted before.

Then from all the points V of this *Epicycloid*, having described the circles N, equal to the circle E F of the little Wheel, the Curve E N N which touches all these circles will be the fashion or form of the arm of the tree, or axis of the Wheel.

Following the same method of demonstration, that I have observed before, it is evident that in whatsoever Position the arm

arm E N N of the axis, shall be in turning about its axis C, it will have always equality of motion between the center of the little Wheel which rises perpendicular, and the point B which it moves about from the center C: For if the center of the little Wheel B is transposed in H, following the line B H parallel to A G and perpendicular to A C, through the Curve E N N transported in L *n n* about from the centre C, it is evident that the point H, will be found on the *Epicycloid* B V V, removed in K H, with the Curve E N N removed in L *n n*: For the shortest distance from the point H to the Curve L *n n*, will be equal to the Radius of the little Wheel E F: But by the Formation of the *Epicycloid* B V or K H, the arch B K of its Base, will be equal to the arch of its generating circle, which is here the right line B H, which represents also the way from the center B of the little Wheel, while the same point B describes the arch B K: But the ways B K and B H being equal, and the Powers equal applied in B, of which the one acts to the end B of the Leaver C B, and the other to the end B of the infinite Leaver B A, or determin'd to what distance you please in A, for the length of the Leavers ought not to be consider'd when the Powers are directly opposite the one to the other, it will follow that you will have on every side an Equilibrium between the two equal Powers.

We do not consider here the rubing or wearing of the handle of the Pestle throughout the hollowing of the wood it runs in, for to make it raise perpendicular, for we suppose that the Bodies are exceeding smooth, and that the rubing or wearing hinder not in any manner the motion.

The Second kind. Fig. 202.

In the Second manner it must be that the arm of the Pestle is of a curve figure, and that the little Wheel is applied to the end of the arm of the Tree, or Axis of the Wheel.

The figure of this arm, or wing, is not determined: Since there is no regard, but to the length from the axis of the tree, even to the centre of the little Wheel, which works on the arm of the Bar, or Pestle; it behoves only to take heed that the Figure as C K D, which we give to this arm, or wing, hinder not the motion of the arm of the Pestle.

Let then, as before, the handle of the Peſtle be A G, and the center of the Axis C, having drawn the Perpendicular C A on A G, mark on A C the Radius A B of the little Wheel, and by the point B draw the line B E parallel to A G, which will be the Baſe of the Cycloid B V V, whoſe generating circle will have the length C B for its Radius: If from all the points V of this Cycloid, we deſcribe the circles N equal to thoſe of the little wheel, the Curve line N N which touches all theſe circles will be the Figure of the crooked arm which we ought to apply to the handle of the Peſtle.

'Tis evident by the generation of the cycloid, that if we move the cycloid B V on its baſe B E, in what place ſoever 'tis placed, as in E D *u*, the end B of the Radius C B being removed by the cycloid in D, the arch B D will be equal in length to the right line B E of the baſe; but if in ſtead of the cycloid we uſe the curve N N, we ſee clearly, as in the precedent propoſitions, that this curve will make the ſame way to the point B, from the end of the Radius C B, in rencountring the little wheel A F, whoſe center is in B; for the curve *n n* which rencounters the little wheel, cannot advance its center, or make it move forward, but from the diſtance of that center to the cycloid, which is that from the Radius of the little wheel: But as theſe motions, or movements, are every where equal, there will be an Equilibrium between the two equal powers applied, as in the precedent example, which does not require any long explication after that which I have ſaid of other Engins.

There is only in this caſe one difficulty for the conſtruction of this Engin; for as it is, that the little wheel lays hold on the arm of the Peſtle below, if the arm of the Axis, or Axletree, which carries the little wheel, be right or ſtreight, it rencounters the curve before that the little wheel touches it; we muſt then bend or make crooked the arm a little, as the line H K D ſhews; to the end that the little wheel begin to rencounter the curve F N N, when its center B is in the line C A: But as it is difficult to make theſe ſorts of curves H K D, unleſs it be of Iron, we may alſo make to ſerve an arm every way right or ſtreight which ſhall bear or carry the center D of the little wheel, but then the arm muſt be double, and the little whe.l muſt be applied between two to the end, for the crooked

crooked arm of the pestle F N N will pass between these two streight pieces which bear the little wheel.

We must observe here, as in all the other Engins, that the little wheel be small; for when the crooked arm which it rencounter or meets, ceases to work by a perpendicular line drawn from the center of the little wheel to the curve, it ought to cease in the Rencounter, or discontinue to meet it, which is not possible, because it serves but one part of the Curve: It happens then that the extream of the arm works still by its point on the little wheel, in making it turn on its center until it be entirely got away, and in the motion, the *Equilibrium* between the powers is not found any more, which is a defect in the Engin, which we must avoid and lessen by making the little wheel of a small Diameter.

PROPOS. XI.

Of the Length and Disposition of the Teeth of Wheels.

Fig. 203. I Have already demonstrated, that it is not necessary that the teeth be equally distributed on the wheel, when they are of a regular figure to make them act equally one with tother; for if we have but one, it will be as if we had more which work, the powers applied to these wheels act always in the same reason or proportion, the one with respect to the other. But we must take heed that when one tooth as O N L, which is cut as L, ceases to work on the other Tooth P Z, that is to say, when the Touchant in L of the curve O N L, is also Touchant in the same point L of the curve P Z of the other tooth, there must be two other already of the two wheels which work together; for otherwise the extream L of the tooth N L rencountring still only by the point L, the curve P Z will not be moved as before, and the motions of the two wheels will not be equal between themselves: It is not possible in this case to rectify the motion in seeking the figure which rightly agrees with the Teeth of the wheel A, to make the point L work equally on the Tooth P Z; for the point L rencounters the Tooth P Z, in the same points where it already is rencountred by the curve N L. But when another tooth begins to work, or hath workt already, when the point L ceases to work regularly on the Tooth P Z, the point L ceases also

to rencounter the tooth P Z; but because the wheel to which 'tis fastned is moved always with an equal motion by the rencounter, or meeting of the other teeth of the wheel G, which makes it go further than the point L alone should do, for this wheel A will have always the same way, as if the Tooth P Z should be rencountred, or met, by the curve O N L prolonged, or lengthned; then the point L will remove aside from the tooth P Z, and they will work together only so much as they can do it regularly, which is a great advantage to an Engin.

We ought also to take heed that the Teeth of one wheel rencounter not those of the other wheel above the points, where they ought to begin to work, that is to say, towards G, above the line A C, which joins the centers of the wheels for the reason of rubing or wearing, as I have already taken notice of before, for the rubings which are made of bodies, which go one on another are always very great, and on the contrary those that are made by slipping, are very inconsiderable, wherefore we ought to dispose the Teeth in such manner, that they trouble not, nor hinder one another before they begin to work, and that there be a convenient length and depth given them, for power to disengage themselves easily the one from the other.

We may yet note, as I have done, that the part of the tooth which works not, may have what figure you please, and that we ought only to seek those which gives it most constancy or stedfastness, and which may serve for disingagement. Nevertheless it is left to be done as workmen use in their common discoveries of giving to teeth the same figure of both sides, as well to inure to make these teeth all equal, as to serve also to the motion of the Wheels, when we would make them turn in a sence contrary to that which is necssary for the use of the Engin; which we are oblieged to, oft-times in the building and taking of them too pieces.

Fig. CXCVIII.

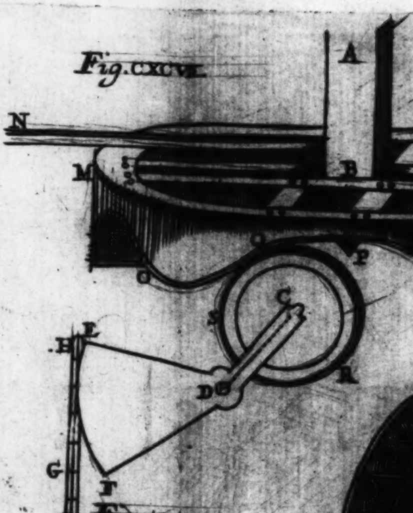


Fig. CXCIX.

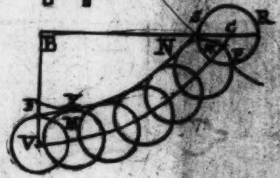


Fig. CCI.

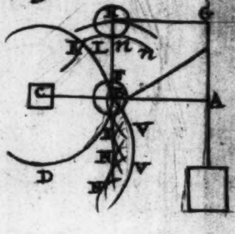
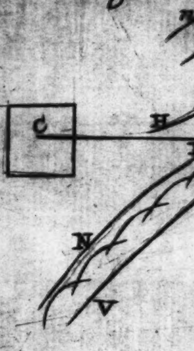


Fig. CCII.



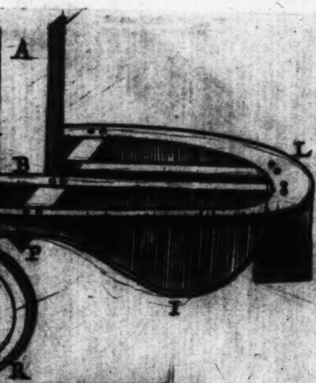


Fig. CXCVIII.

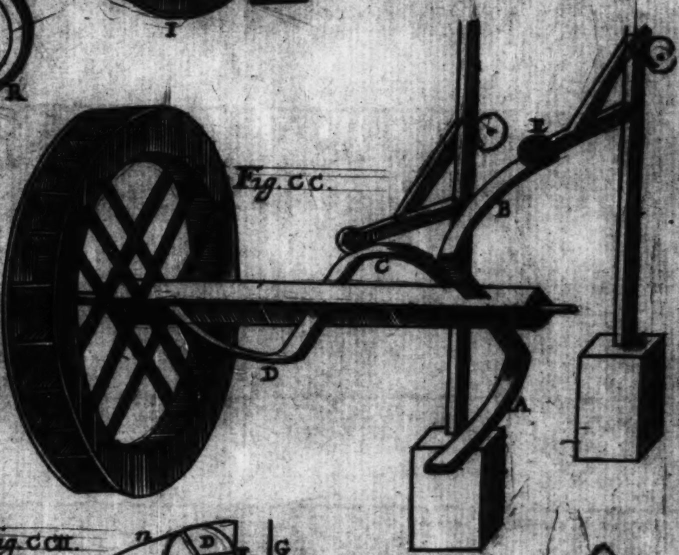
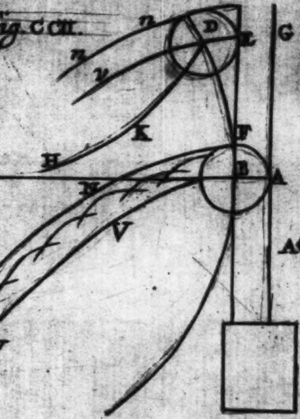


Fig. CC.

Fig. CCII.



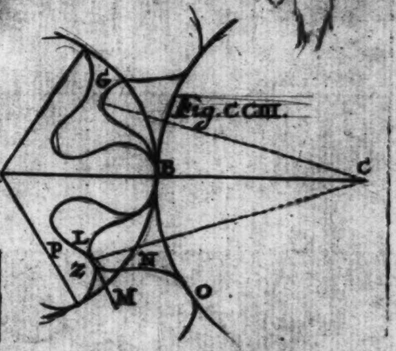


Fig. CCIII.

PROPOS. XII.

To make an Engin which serves to move several Saws for the sawing of Stones. Fig. 204.

AB, is a Frame, or Shas, in manner of a square figure, which may move easily from C towards B, and from B towards C, being kept within a kind of hollow gutter of wood, in which it moves on little wheels which are fastned to a piece beneath: In this Frame you have two pieces of wood joined at right angles in G and in F, with the pieces of the Frame A M, C B, and which are detained by two bonds or braces from the sides of the Frame, there must be also in the two other angles of the frame two bonds or braces in D and in E, which serve to strengthen it.

In the middle of this Frame there must be a Triangle of wood H I K, which is sustained in the middle on a large piece of Timber, or Axle-tree L, on which it is well stayed, and when this large piece of Timber, or Axle-tree, turnes, the angles of the Triangle, which are furnisht with small little wheels in I K H, come to rencounter the pieces of wood G F one after another, making the frame A B to move from one side to the other in the hollow gutter, by forcing it in G, and afterwards in F.

Towards the ends of the pieces of wood A M, C B, there must be two rods of Iron, as M B, which must be well fastned, which must bear two hands of iron N O, which may run along these rods of Iron, where they are engaged at one end, and on the other they are well fastned to one of the arms of the saw P. Whence it appears, that when the Frame is moved, it makes the saws P to move which are on the two sides of the frame; and according as the saw works, the hands descend by running along the rod M B.

According to the force of the power which turns the axle-tree L, we may apply many Triangles, as H I K, which will make to move so many Frames, as A B, which makes to go, twice as many Saws.

The little wheels which are applied to the angles of the Triangle, and which facilitate the motion of the frame, are of great use, because they take away the rubing, which would

be

be made against the pieces G F, if there were none but the angles of the Triangle which hit against them. But although these little wheels are applied to the angles, the motion is nevertheless unequal; and for to make it equal, it behoveth that the faces of the pieces G F which are rencountred, or hit against by the little Wheels, must be formed in a crooked line, which is demonstrated and explain'd all along before in the Treatise of *Epicycloids.*

Fig. 205. How to make the bending of the face of the pieces G F; from the centre L, and with the radius L I, equal to the distance which is between the axis of the tree L of the Engin, and the centre of the little wheel, having described the circle I F, draw a part of the Cycloid I S on the right line I Q, which touches the circle in I, and which will be the base of the Cycloid, the circle I F being the generator, and the beginning of the Cycloid being in I; then on all the points of the Cycloid, as a centre, describe the circles R which must be equal to the little wheel, and you may draw the line R R, which will touch all the circles towards the convexity of the Cycloid. The line R R will be the bending of the face of the pieces G F: We may prolong the line R R towards V, adding to it a part of the right line, even to the place where it is fastned in the piece A M of the frame: You must observe, that the little wheel in working ought to apply it self in the curve or bending R R, in the same manner that the circles R R are placed, that is to say, that the pieces G F ought to be a little more bending towards the middle of the Frame.

PROPOS. XIII.

To change the direction of Motions, or Movements, by the means of toothed Wheels. Fig. 206.

LEt the wheel be A B which turns on a vertical Tampin C, whose teeth are placed perpendicularly on the plane of the Wheel.

If we would move this Wheel A B Horizontally, by means of the arm D E, and that its teeth rencounter, and enter in the Spindles of the Lantern G F, which moves on its Horizontal

Tampin

Tampin M N, it is evident that the Horizontal movement of the Power applied to the arm D E will be changed into a vertical movement or motion about the Tampin, or the Axle-tree M N, of the Lantern.

Also by means of an Horizontal motion we may raise the weight P, whose Chord is wound about the Roll O, which hath its axle-tree common with that of the Lantern F G.

But if instead of the Lantern F G, whose spindles are parallel to its axle-tree, we would make another, as H I, whose Spindles are inclined to the axle-tree K L, in what angle we please; it is evident, that the horizontal motion of the power applied to the arm of the wheel, will be changed into a motion inclined to it, in what angle one will about the axle-tree K L.

Only note, that the Spindles of the Lantern H I, which rencounter the teeth of the wheel A B, must find themselves places horizontally in the rencounter, to the end, that they may be applied in the same manner, as if this Lantern were like to the other G F.

PROPOS. XIII. *Fig.* 207.

The description of a Wind-mill, together with the Computation of the force of the Wind on its sails.

THey are commonly of two sorts, but they differ not but in this, that in the one the whole body of the mill turns on a Tampin, to expose the sails to the wind; in the other, the body is of stone, and none but the upper part turns to expose the sails to the wind. In these the Lantern and the stones ought to be placed in the middle of the Tower, that the teeth of the Wheel in all their different Positions may rencounter always equally the Spindles of the Lantern.

A B is the great Axle-tree, at whose end the Sails are fastned, and which serves for an axle-tree to the Wheel C D. The teeth of the Wheel C D enter into the Spindles of the Lantern E F, whose Axle-tree G H N is vertical, and which being stayed by the upper stone I K, makes it turn on that beneath L M, which is immovable.

So that the vertical motion of the Sails, and of the Wheel is converted into the Horizontal motion of the stones.

The Wheel hath commonly 48 Teeth, and the Lantern 10 Spindles, so that each turning round of the Wheel, or of the sails, causes near 5 turnings round of the stones to be made; whence you may observe, that perhaps the stones make not the whole, or more than one turning round, in one Second of time, and by consequence the sails will also make one turning about in 5 seconds: Therefore if the wind be to violent, we abate one part of the sails to reduce them from this swiftness.

It is not likely that the ordinary manner of using the force of wind, to turn the stones of mills is the most advantageous that is possible to be found, which is that which hath oblieged many active workmen to seek after, other sorts of Mills to the wind, and above all the Horizontal, to the end that the sails may be exposed directly to the wind, and profit by all its force; but all these sorts of inventions have not prospered. We may perhaps believe that the Wind-mills, such as we have seen were not made at first sight in the perfection that they are at present, but that the continual use which is made of them, hath made many defaults to be seen, which one amends afterwards.

Behold the Computation of the force of wind against the sails of a mill, according to the inquiry which was made by Mr. *Mariot*, in his book of the *Motion of Waters*.

Fig. 208. A B represents in this Figure the Axis or Axletree of a turned Cylinder, and the Rule G H a cross at right angles: And I L is another rule, placed perpendicularly on the first G H, and stayed also in the Cylinder. M N O P is a small thin table, even as the precedent Rules, which is likewise placed perpendicularly on the Axis A B, and Bias so, that it makes with it an angle of 45 degrees, and with respect to the Rule G H.

If we suppose now that one Cast of water beat directly against the Rule I L, towards the point Q, and that it turns the Cylinder according to the order of the letters *a b c d*, but that the weight R placed towards the end H, of the Rule G H, makes an Equilibrium with the force of the cast of water Q, that is to say, that it hinders the Cylinder from turning; It is certain, that if the same cast of water beat against the Table M O, also in the point S, which being also so far removed from the Axis of the Cylinder, as the point Q,

and

and that the direction of this Cast be perpendicular to the Table, it cannot support the weight R, because that its direction will not be according to the motion of the Rule I L, which is in a plane perpendicular to the Axis A B; but it cannot at that time support that weight which shall be to the weight R, as the side of a Square to its Diagonal.

And if the same Cast is parallel to the Axis A B, and that it hit against the Table M O in the same point S, it must still diminish in its attempt in the same Proportion of the side to the diagonal of a square, because that this Cast falls obliquely against the Table under an angle of 45 degrees.

It is then evident, that this double reason of diminution ought to reduce the weight R to its moyety, or half part.

Now the wind which beats against the sails of a Windmil, beats, or blows, obliquely, and if it rencounters each sail under an angle of 45 degrees, it follows then from what hath been said, that it will not have but a moyety of the force which it would have, if it rencountred directly, and if the sail, be placed on the Axle-tree, as the Rule I L on the Axis A B. If we suppose then that the whole force of the wind be as 80, it will be redcuced to 40 for these two causes.

But there is yet one cause of Diminution of the force which comes from the same obliquity, for it will have a less breadth of wind which rencounters the surface of the sail, than if it had been directly opposite, and this diminution will be still in the same reason, or proportion, of the side of a Square to its diagonal, which will in the end, reduce the whole force of the wind measured by 80, to $28\frac{1}{4}$.

But if the obliquity of the sail is less than 45 degrees, that is to say, if it is more exposed to the wind, whereof we suppose the direction parallel to the axis A B, and that the angle be of 60 degrees on one side, and 30 on the opposite, then the first cause of diminution reduces the force from 80 to the moyety 40, but the two others unlike, for they reduce not but from 40 to 31 very nigh; which gives us to understand, that it is better that the sails of windmils have this obliquity than that of 45 degrees.

By these suppositions of Mr. *Mariots*, if the swiftness of an indifferent wind is of 24 feet through each second of time, as one may know by experience; one wing or sail directly opposite to the wind, and which hath 144 feet in its superficies

will sustain a weight of 210 pounds, if the distance from the support, or the centre of motion, as the Axis A B in the precedent Cylinder, even to the place as R, where the weight is placed, is of 12 feet from the same, as the distance from the centre of the sail.

But if the sail have only 6 feet in breadth, and 24 feet in length, it will have the same superficies of 144 feet, and its Centre will be also 12 feet from the Axis; wherefore it will sustain as yet the 210 pounds, having 12 feet of distance from the Axis: But if the distance from the axis to the Centre of the sail is of 15 feet, it will sustain 262 pounds and $\frac{1}{2}$.

But through these three causes of diminution they suppose the angle of the sails of 60 degrees, with the Tree, or Axis, where they are fastned, the force of the wind reduces it self to sustains 101 pounds and $\frac{3}{4}$, having 15 feet of distance from the Axis: And because there are four sails, the force of the wind will sustain 407 pounds at the distance of 15 feet from the Axis of the sails.

But the semidiameter of the wheel being supposed of four feet, if we make it as 4 to 15, so 407 to 1526, this will be the number of the pounds which measures the force of the wind against the Spindles of the Lantern, in the supposition that it makes 24 feet in one second; there is no regard of the rubing, or wearing, in all these Calculations.

In the horizontal Mills you cannot have about but one sail, against which the Wind acts directly, and it must be made of an extraordinary greatness, for to cause the same effect as the 4 vertical sails of ordinary Mills, as 'tis easy to compute by the precedent Suppositions.

PROPOS. XIV. *Fig.* 209.

Of Wheels, and of Lanterns, with their Elbows, or crooked Axes, for the moving the Suckers of Pumps.

IF the power turns the wheel vertically, we must only bend the ends of its Axis, as you see here in the figure G H. But if the motion of the power be horizontal, as if it be applied to the arm C D of an horizontal wheel A B, you must adjust the Lanterns E F, so that their Spindles enter in to the

the teeth of wheel, and that their crooked axes may work the effect that we desire.

In each crook of the Axis you may put a kind of little ring I, which is fastned to the end of the Iron of the sucker K, so that in the motion of the Lantern, the crooks of the Axes raise them and let them fall alternatively, or by turns one after another, these raise and depress the Pestles, or Irons, to which the Suckers are fastned in the body of the pump, this also makes it give one stroke of the Iron to each turn of the Lanterns.

We may make the diameter of these Lanterns a fifth part very nigh of that of the great wheel, to the end, that for each going round of the great wheel, the Lanterns may make five. But however commodious this Proportion is, we will not make a Rule, because it must have regard to the swiftness of the power which may be too great for this proportion, and which will move the Rods, or Pestles, too nimbly.

PROPOS. XV.

In toothed Wheels the number of Teeth must not contain exactly so many times the Teeth of the Pinions, or Spindles of the Lanterns to which they are applied.

THis Rule concerns only the execution, and we ought to have regard to make it so, that the teeth of the wheels do not always rencounter the same teeth of the Pinions, for when they rencounter, or meet different ones, they grow perfect in rubing and in using themselves one against the other, and by degrees they make very nigh the figure which behoves them, for to act equally in their different rencountes, and in the different lengths from their Axes, which is explained in the Treatise of *Epicycloids* before.

It behoves to practice this Rule exactly, that the number of the teeth of the Wheels, and of the Pinions, must be Primes between themselves, that is to say, that they do not admit of any other common measure than Unity, and so the same tooth of the little Wheel, or Pinion, rencounters not the same tooth of the great Wheel, but after that the little one hath made so many revolutions, or turns, as there are teeth in the great wheel.

But

But because there is but little difficulty to make one division of two prime numbers, we may make the number of teeth of the great Wheel; for example, of 48 or 60, and those of the Pinions of 6 or 8, and in the Mills, the great Wheel of 48 teeth, and the Lantern of 10 Spindles, to the end that the same teeth may meet as few times as is possible; for if the Wheel have 60, and the Pinion 6, the least numbers which keep the same proportion will be 10 and 1, wherefore the same teeth of the Pinion of 6, rencounter not them of the Wheel but after 10 revolutions; and if the great Wheel have 60, and the Pinion 8, the teeth of the Pinion rencounter not the same teeth of the Wheel, till after 15 revolutions, because that 15 and 2 are the prime Numbers between themselves, which express the relation of 60 and 8: Lastly, if the Wheel have 48 teeth, and the Pinion or the Lantern 10, the teeth of the Lantern rencounter not the same teeth of the Wheel but after 24 revolutions, for the numbers 24 and 5, are the two prime numbers which express the relation between 48 and 10, and 'tis this which makes us see that we cannot find a number of teeth which is more proper for the Wheel, and for the Lantern of Mills, for the division into 48 parts is easy, and may be done very exactly, and that of 10 is commodious, and may be reduced to 5.

PROPOS. XVI.

Of oblique and interrupted Movements, or Motions.

Fig. 210. IF the chord D of the weight P, be wound about on the roller of the beam G, and that the chord F which ought to draw the little wheel E, by means of the pulley L, on which passes the chord F, for to go to fasten it to the top of the little wheel E, passing also on another pulley I, which is fastned to the top of the little wheel E, and which is stayed at last in M towards the pulley L; 'tis evident, that when the roller turns round for to draw the chord F, it windes at the same time the chord D, which is twisted on the roll G, in a contrary sence of the chord F: But if the chord F is twisted on the roll G of 6 feet long, the

weight

weight P descends at the same time from 6 feet high, and will also at the same time be raised by the motion of the little wheel throughout the hollow it runs in.

But the Chord F having been drawn the length of 6 feet, it will not make the little wheel to advance but 3 feet; for as it passes through upon the pully I, and is stayed in M, it doth not advance the pully I, and the little wheel E, which are fastned together, but the half of its movement, or motion.

Wherefore when the chord F is twisted on the Roll G of 6 feet long, and that the chord D is also twisted or wound about of 6 Feet in length, the little wheel E will not have made but 3 feet of its way; and by consequence the weight P will not be raised up again, but 3 feet by the motion of the little wheel E; it appears then to be descended 3 feet, which is so much as the little wheel hath made of way on the hollow groove, wherefore it descends by this means by half a right angle, or it descends so much as it advances.

Lastly, if the chord D which is fastned to the round beam, is all wound up, and that it begins to wind it self about in the same sence as the chord F, then the weight P rises again; but it rises three times as much as it advances towards L: For if the chords D and F are wound about of 6 feet on the Roll of the round beam, the weight ought also to be raised to the height of 6 feet by means of the chord D, and it ought also to be raised 3 feet by means of the little wheel E which draws it, and which passes over 3 feet, while that its chord is drawn 6 feet; then the weight will be raised 9 feet while that it runs over only 3 feet in length, which is the motion of the little wheel E.

But when the chord D is wholly wound of the round beam, or cyclinder, and that the weight begins to rise, if you make a stop to the chord F, as in R, in place which it passes at that time over the pulley I, so that the cord cannot any more turn on the pulley, the same thing will happen as if it were fastned at the top of the little wheel E, and the weight will be raised 6 feet, by the motion of its chord D, and 6 feet by the motion of the little wheel E, it will then have run over 6 feet in length hanging, while it is raised 12 feet.

Now if the parts of the Roll of the round beam on which the cords D and F are wound, are of different diameters, it will make the movements or motions, different, and in different

pro-

proportions of those which I come to explain; but it will be easy to determine them, the Diameters being given, or else, the motions being proposed, it will be easy to find the Diameters of the Roll which will serve them.

We may also by the same means make it so, that one part of the way of the weight shall be Horizontal, and the other part rise or descend perpendicularly, or obliquely, which requires no long Explanation; I shall say no more of circular motions in rising, or descending, seeing they only depend or belong to the figure of the hollow groove. There is in an all these motions many little cautions to be observed, which must be left to the industry of the Artificer.

We may also make many motions different and opposite the one to the other, with one and the same motion, by the means of pulleys, referring from one to another which change the direction of the motions, which serve chiefly to make the changes of the Decorations, or Ornaments, of the two wings of Theatres; for one axis only A (*Fig.* 211.) which bears the Tambours, or Cylinders B C, of different diameters, coming to turn by means of a counter poise, or weight, makes to advance towards the middle of the scene beneath the Theatre, the false frames or shashes D, which bear or carry the Ornaments or Decorations by the means of the chords C E, B E, which are fastned to these shashes, or frames, and which are wound about on the Tambours in a contrary sence: These same shashes D advancing, and those of G retiring at the same time, whose place they take, by means of one or two chords I, which are fastned to these two shashes, which pass above the pulleys that refer from one to another H, which are those in the walls of the two sides. The motion or way of these two shashes will be more or less according to the proportion of the Tambours, or Cylinders, which bear the cords of their motion.

Prop.

PROPOS. XVIII. Fig. 212.

How to raise a weight by an oblique motion.

LEt the weight be P which is to be raised obliquely from P to A, the Engin which serves for the movement being at the height of A.

Make a hollow groove A B composed of two pieces of wood which are only removed one from another, so much as to leave room for the chord to pass freely which sustains the weight P, and which must be placed Horizontally; the chord C D H which sustains the weight P, is stayed firmly in C towards the end B of the hollowing, and passes in the overture between he two pieces of wood of which 'tis made; it passes also above the little wheel E composed of three pieces, *viz.* of two little wheels, or rollers, at its ends, and of one pulley between two, on which passes the chord C D H. Towards the end A of the hollow groove there is a Cylinder, or round beam G with its arms for to draw the cord F, which is fastned to the top I of the little wheel.

'Tis easy to behold by the construction of this Engin, that when the chord I F draws the little wheel E from B towards A, the weight P raises obliquely, or a slant, from H to A, and that the elevation of the weight P will be equal to the length of the hollow groove A B.

We may also make it that the Elevation of the weight P shall be in what proportion we please with its Horizontal way; for Example, that the weight P be raised 20 feet hanging, while it passes over 60 feet Horizontally.

For this effect we may place the motion of the chord F, which draws the little wheel E from B towards A at the end B of the hollow groove with a pulley towards A.

Also the round beam, or Cylinder, being placed towards B which draws the chord F, will advance the little wheel from B towards A. But then it will cause the cord C D H which sustains the weight P to be twisted on the roll of the round beam, and that it will not be fastned immoveably in the point C, as before; the place of the roll where it is twisted, must have its diameter smaller than the same where it twists the cord F, when the Cylinder makes the little wheel E to advance on the

hollow groove, and then the chord D will be twisted in a contrary sence to that of the chord F, to the end that it may wind off, as the other twists about. The proportion of the diameter of the part of the roll of the round beam where the chord F winds about, to the diameter of the other part where the cord D is twisted, or wound about, ought to be as the Horizontal way to the difference of the two ways, which is the same as 60 to 40, or as 3 to 2. For then when the chord F draws (for example) the little wheel E on the hollow groove through the space of 6 feet, that part of the roll where the chord D is twisted will have wound 4 feet, and by consequence the weight P will not be raised as yet but 2 feet, although it have run over 6 feet of Horizontal motion.

It will be the same thing for any other proportion of Elevation; only we must Note, that if we would have the weight P make a greater motion in height than in length; for example, if we would have it rise 30 feet hanging, while it runs over but 10 feet in length on Horizontally, it behoves that the diameter of the roll for the chord F be made to the diameter of that part of the roll for the chord D, as 10, which is the Horizontal way, to the difference 20 of the two ways. For if to each bout of the Cylinder the chord F make 3 feet of way, the chord D will make 9, for the circumferences of the rolls are in the same reason or proportion as their diameters; and by consequence the weight P rises 6 feet, because of the diameters of the parts of the roll, and it rises still 3 feet in the same time, which is equal to the Horizontal motion.

As to the swiftness of the motion we may give it what we please, for if the cylinder cannot draw the chords which make the motion with so much swiftness as we require, it must be done by means of a counter weight very heavy, which we may raise to an height equal to the Horizontal motion, and having fastned this counter weight to a chord wound about on the roll, where the other chords which serve to the motion are likewise twisted, but in a contrary sense, when we let loose the counter weight it will turn the roll with a great swiftness.

We commonly moderate this motion by means of a chord, which serves to make the tricker, or detainer, and which being applied against any body where it slips and retains afterwards, with the hand we may let it loose to such a proportion of swiftness as we would give to the Engin.

Fig. CCIV.

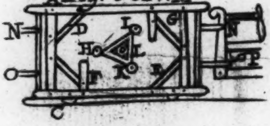


Fig. CCV.

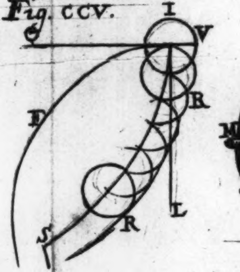


Fig. CCVIII.

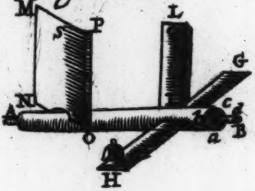


Fig. CCVII.

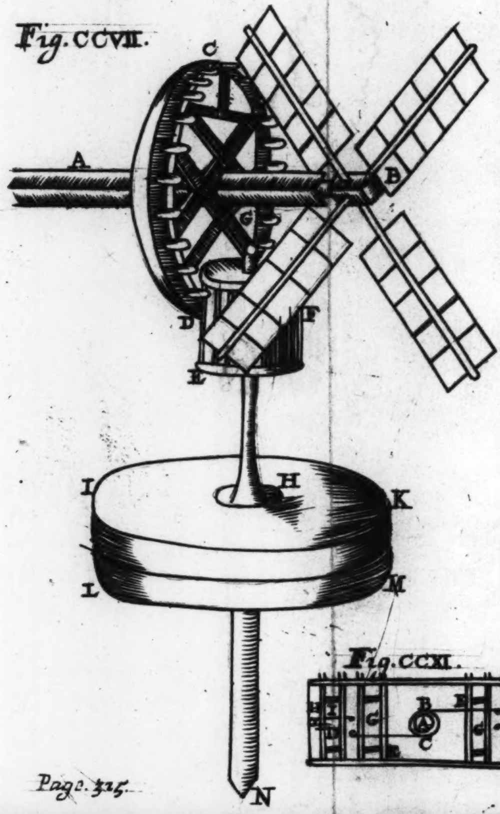


Fig. CCXI.

Fig. CCVI.

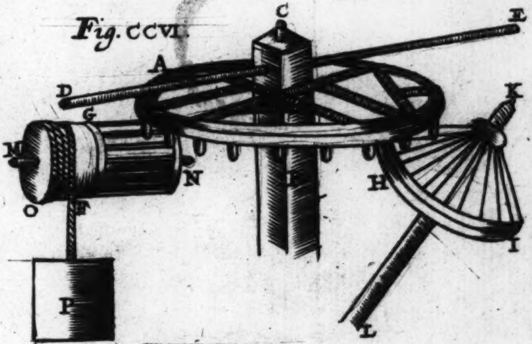
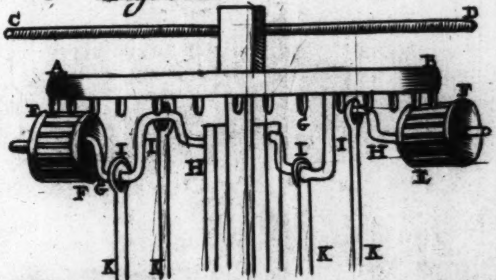


Fig. CCIX.



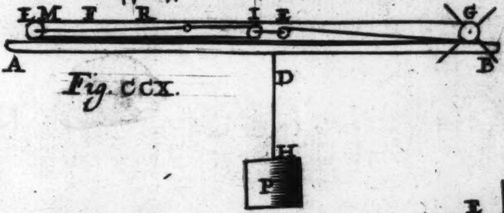


Fig. CCX.

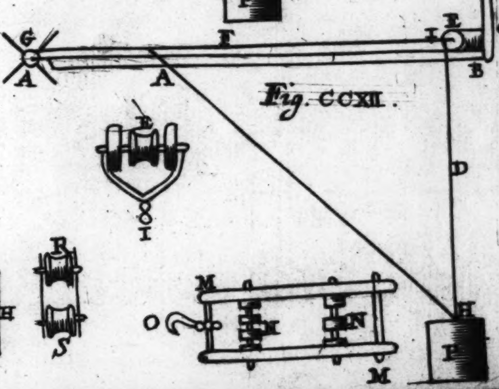


Fig. CCXII.

XI.

This ſame tricker, or detainer, ſerves alſo to render the motion equal, which will otherwiſe be very unequal becauſe of the acceleration of the counter-weight in deſcending.

When one chord ſerves it ſelf, of many which are placed one from another for to raiſe the ſame weight, or which is the ſame thing, which ſuſtains it in ſeveral places, there muſt be inſtead of the little wheel E, a ſhaſh or frame of wood, uſed as M M, in which there muſt be rolls, as N, which ſerve with the pulleys to paſs the chords above, theſe rolls turn on their Axes which enter in the long pieces of the ſhaſh or frame. This ſhaſh muſt run along on the two pieces of the hollow groove, being drawn through the hook O where we faſten the chord which ſerves to its motion; but it behoves that the ſhaſh be kept on the hollow grooves that it fall not from one ſide to the other.

We may alſo inſtead of the hollow grooves, make one chord only to ſerve, being well ſtretched out, on which muſt paſs a pulley, as R, which ſuſtains another S, which ſerves to ſuſtain the chord of hanging motion which the pulley R runs along in, in rouling on the chord which ſerves for the hollow groove.

I ſhall not ſay any thing concerning the manner of making theſe hollow grooves, and their detainer in different places to render them ſolid, becauſe it belongs to workmen, which work in Carpentry or Joynery.

We may alſo make of theſe ſorts of movements which croſs themſelves without trouble or confuſion, for if one ſerves to the ſhaſh, as I have explained before, it is eaſy to ſee that the hollow grooves may be cut and interrupted in any place in a ſmall ſpace of 4 or 5 inches, which may ſerve for the paſſing of the chord which ſuſtains the weight, which moves it ſelf with a different motion from that which is borne on the hollow groove which is cut, without which the motion of the weight will be hindred; for the ſhaſh having its long pieces ſupported on thoſe of the hollow groove, it may paſs eaſily above the overture of the hollow groove.

What I have ſaid concerning the raiſing of Weights, may be applyed to their deſcent.

FINIS.

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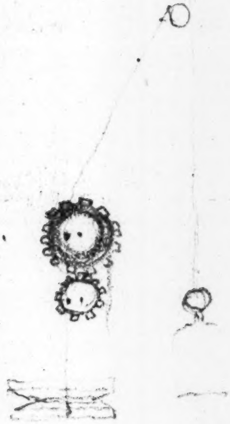
ERRATAES mended thus:

Page	L.	
3	27	To the Proportion.
4	12	with.
5	30	Strike out [*be*]
7	10	Less.
11	20	Will.
11	31	Leotaudus.
12	5	A B.
12	ult	the Comma to be after [*before*]
13	36	strike out [*they should have*]
13	37	strike out [*they should have*]
14	13	Proposition IV.
27	12	Hang a thred
28	30	*c* in like manner.
39	5	Distant.
41	15	Foremost.
53	5	Strike out [*in*]
53	20	Leaver.
53	23	then E M.
53	24	and D O.
53	26	strike out [*in*]
55	6	add [*or rubing*]
57	12	Axis.
	14	Axis.

Page	L.	
58	1	58 and p. 59 l. the first [59]
62	1	62 and p. 63 l. the first 63
65	9	hands.
75	12	Tube.
	19	Tube.
85	22	then.
88	25	Fig. 73.
89	9	the
90	25	Fig. 74.
91	29	will be tripled.
96	23	of.
96	24	abundant.
99	16	some things.
100	9	The whole circumference of the circle described by the wood, would be compared with the line N O.
105	27	remain.
106	2	strike out [*the*]
117	5	strike out [*it*]
124	33	strike out [*the*]
125	27	strike out [*the*]
126	9	strike out [*too*]
128	22	when.
129	28	to the hindmost.
130	14	strike out [*be*]
134	14	and a little.
137	2	Bucket M being
139	16	raised into line the 18, then.
142	*last*	Silken.
144	25	must.
145	12	rise.
146	7	mixt.
147	34	K H.
149	2	K L ; line 25 H N
150	27	that is it.
151	23	Cabeus.
152	12	B D.
153	25	B D.
160	26	in,
163	40	Feathers.
166	*last*	proceeding.
170	10	of the Centre.
173	19	but only.
176	5	with a Semicylindric.
179	17	no extream end of.
182	29	by shortning the rule.
183	18	for in Fig. 129. let.
184	12	the Jags.
185	20	lightly.
185	22	a
185	31	Problem, V.

Page	L.	
186	37	consist.
187	2	wearing.
188	7	equality.
191	6	by the way:
191	17	Slowneſs, line 19. Clocks, Meaſure.
191	25	alwaies.
192	3	require greater weights; line 35, then
194	5	adapt: line 19, applyed.
194	31	ſtrike out [*an*]
196	33	wings.
197	18	in an hour.
203	32	thickneſs, line 30, add Fig. 142.
206	14	to be uſed.
209	33	prefixt.
215	8	third Minutes.
217	1	217; and ſo gradually in the number of Pages.
220	19	one: line 30, ſtrike out [*the*]
221	1	221, &c. line 7, the
223	1	223, &c. gradually.
224	33	plate.
227	17	its hand: line 30, Artifices.
227	33	make a Comma after Indexes.
230	2	dividing: line 7, a Quadrate.
230	8	ſtrike out [*and*]
231	28	they.
232	19	interval.
233	5	Wheels.
234	9	after [*table*] make a full ſtop.
236	28	B to C.
237	14	Syſtem. line 24. perpetually.
238	17	Leaves.
271	7	leave out [*left*]
271	12	paſs.
275	10	Flexible.
276	10	ſtrike out [*to*]
292	19	re-enter.
296	7	C V.
297	27	Axis.
298	3	Effort.
303	19	they come.
305	20	Prop. XIV.
308	15	ſuſtain.
308	30	Prop. XV.
309	17	Prop. XVI.
310	25	Prop. XVII.
311	31	Cylinder.
311	32	in the place.

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